WORLD RESOURCES INSTITUTE

WRI REPORT

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MATERIAL FLOWS ACCOUNTS

A Tool for Making Environmental Policy

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EXECUTIVE SUMMARY

As industrial economies mature, the heart of the environmental challenge comes from maintaining the continual flow of goods and services to satisfy society's needs for housing, food, energy, transport, and recreation while not destroying the natural resources that underlie the economy. The way society meets its needs determines the types and amounts of materials—ranging from fuels and timber to fertilizers and metals—that flow from the environment, through the economy, and back into the natural environment. Environmental consequences, good and bad, depend on the way a material is extracted, the nature of its release, how much is released, how it is released, and where it flows throughout its life cycle. A coherent approach to accounting for the flow of materials integrates two major concerns: the capacity of ecosystems to provide natural resources for extraction and use and the capacity of the earth and human society to handle pollution, greenhouse gases, toxic contamination, and other wastes.

Material Flows Accounting (MFA) tracks the amounts of materials—as classes or individual substances—that enter the economy, accumulate in capital stock such as housing and automobiles, or exit to the environment as waste. In short, MFA documents the commercial life cycle of materials that become part of the industrial economy, from extraction, processing, and manufacturing to use, reuse, recycling, or disposal.

National Income Accounts, initiated in the 1930s and formalized in the federal government in the 1940s, still provide a foundation for U.S. fiscal and monetary policy. The need to provide these numbers is now taken for granted. Government leaders and managers would not think of making fiscal or monetary policy without them. Members of the public look to indicators based on these accounts to make their decisions. Similarly, companies and investors cannot do business without the numbers from financial accounting. Yet policymakers, firms, and the public lack any similar set of numbers for the material flows that are at the center of environmental issues.

This policy brief explains why material flows are critical to environmental quality and proposes next steps for monitoring them by establishing a material flows accounting framework for the United States. It describes a pilot database and the material flows data sheets (MFDSs) that would be used for organizing data to be entered into the database. Such a database would supply sufficient detail for supporting national policies intended to stimulate more productive use of resources and reduce environmental releases of materials that harm human and ecological health. The ultimate goal of this effort is to encourage and support the regular compilation and dissemination of material flows accounts (MFAs) in the United States by the federal government.

Findings

Material flows accounts provide a foundation for making and evaluating environmental policy decisions at both strategic and operational levels. MFA data offer government leaders a sound basis for setting strategic targets and tracking the effectiveness of environmental policies. The data can also help policymakers understand and deal with the origins of specific environmental problems. MFAs provide the data to support environmental performance indicators in much the same way that the national economic accounts support such economic indicators as expenditures per capita, debt/equity ratios, and the gross domestic product (GDP).

During the mid-1990s, an international team led by the World Resources Institute (WRI) generated national estimates of material inputs in the economies of four industrial countries—Germany, Japan, the Netherlands, and the United States—and published the findings in 1997 in *Resource Flows: The Material Basis of Industrial Economies*. The next phase of the work covered the material outputs for the same four countries plus Austria. The results were published in 2000 in *The Weight of Nations: Material Outflows from Industrial Economies*.[1]

Analysis of the indicators published in *The Weight of Nations* showed that, while industrial economies may be using materials more efficiently as their economies expand, total waste generation continued to increase in all of the countries considered. The WRI study also found that outputs of some hazardous materials to the environment had fallen or stabilized. However, the total output of potentially hazardous materials had risen nearly 30 percent in the United States between 1975 and 1996, due largely to the growing use of synthetic organic chemicals in products as well as contaminants associated with fossil fuels.[2] Because materials are not uniform in their properties or their potential for environmental impact, indicators of total material flows through the economy need to be supplemented by indicators for individual materials or materials classes. Knowing the amount of output by material or class, especially if distinguished by uses, is a key step toward understanding likely impact on the environment.

At the operational level, material flows data can help identify the sources of environmental problems and the most effective opportunities for policy intervention. For example, when the origins of silver found in the San Francisco Bay puzzled public officials, material flows analysis identified the sources as photo labs and dental offices, which led to a more focused and cost-effective environmental policy.[3] Over the past decade, material flows analysis highlighted the presence of arsenic in a widely dispersed consumer product, pressure-treated lumber. Combined with data on the presence of arsenic in playgrounds and residential decks using the lumber, the use of material flows data helped lead the U.S. Environmental Protection Agency (EPA) to take action in 2003[4] by limiting the use of such lumber.

Material flows accounts provide a basis for choosing cost-effective environmental solutions. Understanding the flow of materials can help policymakers address the shift in pollution sources from one part of the environment to another, for example, from cadmium emissions at mines and smelters to growing stocks of cadmium batteries in solid waste landfills across the country.

More fundamentally, the accounts can identify opportunities to address multiple problems sharing a common origin. For example, the apparently separate problems of a Dead Zone in the Gulf of Mexico and climate change both relate to the increased flow of nitrogen from fertilizers used on farms. Changing fertilizer use addresses both problems.

The accounts can also reveal opportunities for greater national resource productivity by exploiting by-product synergies that reduce waste and save costs as in the case of metallurgical wastes used for cement manufacture[5] or the use of agricultural wastes to replace petrochemical feedstocks.[6]

Material flows accounts can improve communication among policymakers and provide detailed information for public use. MFAs offer a common source of data that technical experts, government managers, and U.S. citizens can use to set targets and track the effectiveness of environmental policies. The indicators can help the public participate effectively in policymaking and provide them with the information they need to make personal decisions such as where to live or where and how to establish a business. By providing easy-to-understand indicators, MFAs can facilitate more informed policy debate on issues such as choosing sites for new facilities and can support more effective changes in how society uses its materials.

Basic data already exist for hundreds of materials, including metals, minerals, fuels, timber, agricultural products, and some industrial chemicals. MFAs can draw from a broad array of existing environmental, resource, and economic data sources within public and private sectors. However, without an agreed material flows framework, these data cannot provide detailed information in a standardized form about the throughput of materials in the economy over the life cycle of those materials. Individual efforts to set policy for a substance across its life cycle entail costly, one-at-a-time initiatives to locate and reorganize information from existing sources and to fill in missing data.

To standardize MFA information, WRI has developed a pilot MFA database that covers material flows for more than 160 primary material inputs as well as many hundreds of outputs. The database is available at <http://materials.wri.org/>.

Analysis of available material flows data for priority chemicals for hazardous waste minimization shows both data gaps and the potential usefulness of standardized data organized by a material's life cycle. WRI's analysis of five substances designated by EPA as waste minimization priority chemicals—cadmium, hexachlorobenzene, naphthalene, pendimethalin, and trifluralin—showed a general lack of data sources for synthetic organic chemicals.

Publicly available data on commercially produced chemicals across their life cycles remain scarce, especially for the use phase and especially as one moves up the value chain from primary feedstocks to intermediates to specialty chemicals. The Census Bureau and the International Trade Commission at the U.S. Department of Commerce have traditionally collected information on domestic and foreign chemical shipments, but such data collection was significantly curtailed in the mid-1990s. While some government offices, trade associations, and independent research institutes do collect some data on chemicals, proprietary considerations have been used to prevent their publication.

The EPA's Toxics Release Inventory (TRI) currently provides standard information on the amounts of about 650 substances entering the environment from industrial facilities, primarily at the manufacturing stage. Data from TRI for the five priority chemicals show an average of 62 percent reduction in air emissions of these chemicals, while TRI data on other releases of these substances and waste transfers show some increases. Remarkably, the amounts of these chemicals going into products remain largely unmonitored by existing systems, even though the products may comprise the main source of hazardous outputs to the environment. By organizing existing data by the stages of a material's life cycle, material flows accounts can highlight flows for which data are now often missing, such as the amount of volatile organic compounds (VOCs) emitted from consumer products, and can offer policy insights.

Experience in developing material flows frameworks is growing around the world at national, corporate, and facility levels. Macroscopic material flows indicators have been adopted in a growing number of countries and are now regularly published by the European Union[7] and some member countries. In Japan, they provide a formal basis for government policy goals.[8] Germany and Japan have both established physical input-output tables that are linked to their economic input-output tables as part of their national environmental statistical systems.

Nordic product registries provide a data source for risk managers and also offer a public database with information on the amounts of several hundred chemicals flowing into the economy, including their use in consumer products. In the United States, New Jersey and Massachusetts require data on material flows from facilities to encourage industrial practices that prevent pollution and to quantify the amount of hazardous material leaving factories in products. At the corporate level, no detailed protocol has yet been developed for reporting on materials, though some companies do provide some material flows data (mostly of outputs of waste and pollution) in their environmental or sustainability reports.

At present, the United States still lacks a comprehensive approach to material flows accounts. It is time to change that. The United States should develop and maintain a material flows accounting framework at the national level. Progress on U.S. environmental problems continues to be tracked for many individual substances, mainly for compliance with pollution control or waste management standards. But, as a previous WRI analysis concluded, "Physical accounts are urgently needed because our knowledge of resource use and waste outputs is surprisingly limited."[9] Stated even more strongly, the Committee on Material Flows of Natural Resources, Products, and Residuals of the U.S. National Academy of Sciences, in its 2003 report, stressed the national need for "a consistent material flows accounting framework to integrate existing and future data."[10]

Recommendations

This policy brief recommends three practical steps toward institutionalizing material flows accounts in the United States:

1. Develop a network of resource, environmental, and economic data providers—including information and statistical offices—to expand and improve the data protocols for compiling and managing the data.
2. Identify the user community and evaluate methods for presenting material flows data that are policy relevant and accessible to the public.
3. Assemble a broad-based partnership of data providers and users to take the lead in institutionalizing material flows accounts, a process that is likely to require a congressional mandate and the creation of a dedicated staff within the U.S. federal government.

1

INTRODUCTION

Material flows accounts (MFAs) track the amounts of materials—ranging from timber and fuel to metals and agricultural products—as they enter and exit the economy through various types of transactions. These materials can accumulate in capital stock such as housing and automobiles or exit to the environment at any phase of their commercial life cycle, from extraction to processing, manufacturing, use, disposal, or recycling. Figure 1 shows the relationship between flows of material inputs and outputs and the phases of a material's life cycle.

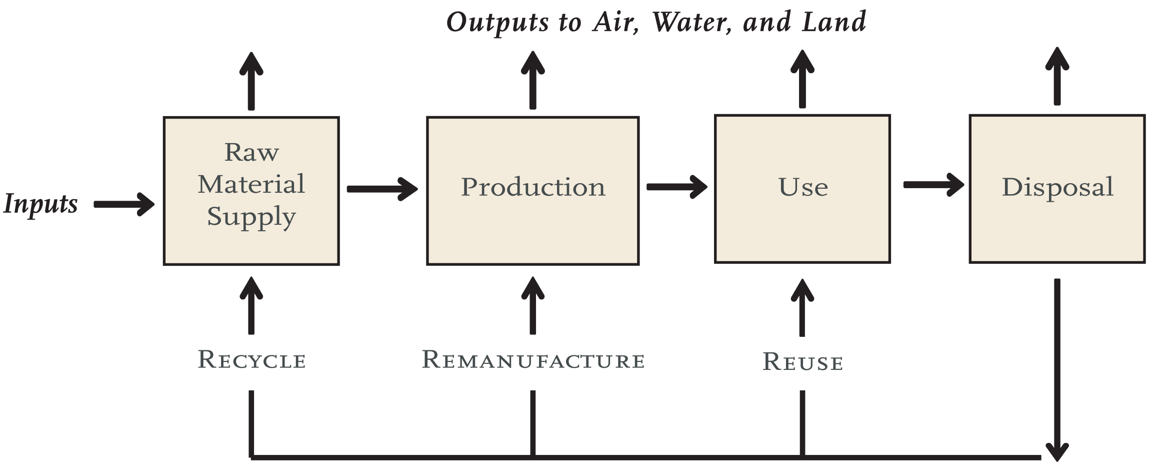
National Income Accounts date back to the 1930s and the 1940s when the United States developed them to help manage the economy during the Great Depression and World War II. Today, they are considered indispensable. Policymakers would not think of making fiscal or monetary policy without the numbers that the Bureau of Economic Analysis and other agencies provide. The same holds true for companies that could no longer conceive of doing business without access to national economic indicators based on the National Income Accounts. To address different economic concerns, some of these indicators rely on broad aggregates of figures from across the economy, while others use data selectively to highlight financial indicators specific to sectors or firms.

Material flows accounts (MFAs) offer another kind of accounting system that can facilitate the integration of environmental and economic policies and prove essential to environmental policymaking. These accounts can help policymakers, business managers, and the public act before problems emerge by pointing to their origins and possible solutions. Similar to national income accounts, MFAs need to support both aggregate indicators and indicators that rely on detailed data on the transactions of a single resource sector, region, or environmental media.

By examining the changes in materials cycles, society will be better prepared to answer such questions as: Are policies serving to break the link between economic growth and the amounts of materials used? Are policies providing incentives for business to design products and processes that avoid dispersion of hazardous materials into the environment? Is use of biodegradable materials in consumer products increasing? Are conversion efficiencies for natural resources to consumer products improving? How are shifts in the nature of the economy (from manufacturing to services and use of information technology) changing the amounts and types of materials used?

Data collection on the flow of materials has been developed in a range of governmental pro-

FIGURE 1 | **THE FLOW OF MATERIALS THROUGH THE COMMERCIAL LIFE CYCLE**



Source: WRI Material Flows Project.

grams.[11] Beginning with historic interest in the mineral wealth in the western United States and supplies of strategic materials during World War II and the Cold War,[12] federal resource agencies have collected data on natural resource production for more than a century. The Interior and Agriculture departments have long taken the lead in collecting data on the natural resources and primary organic and inorganic materials that enter the national economy. Concerns regarding energy supplies and markets during the 1970s spurred the creation of the Energy Information Administration within the newly established U.S. Department of Energy. These activities aim to monitor industrial growth and to provide a national data repository for resource-based industries.

Data on outputs to the environment have developed more recently. The U.S. Congress established the Environmental Protection Agency in 1970. At the same time, Congress began to adopt landmark laws to keep pollutants out of the air and water and to improve the management of wastes. These laws mandated collection of data, in large part to measure compliance with standards limiting pollution levels in the air and water or to track the handling of waste on land.

The inaugural report issued by the White House Council on Environmental Quality (CEQ) in 1970 pointed to the interrelationship of separate pollution problems and recognized that "a systems approach is needed, but what kind of a system? The pollution system, the materials and resources use system, the land use system, the water resources or atmospheric system?"[13] Despite institutional changes that aimed to coordinate environmental and resource protection activities, new laws led to separate programs organized by individual problems such as pesticides or environmental media such as air and water.

BOX 1 | **FINDINGS FROM PREVIOUS WRI ANALYSES**

While researchers suggested material flows analysis and published reports on the materials exchange between the U.S. economy and the environment as early as 1969,[1] progress in establishing a coherent approach to tracking material flows in the United States has been slow. In the 1990s the World Resources Institute (WRI) led an international initiative—including institutions in Japan, Germany, the Netherlands, and later Austria—to advance the use of material flows accounting as a basis for national indicators that would help measure environmental performance. The initiative generated national estimates of material inputs and outputs and proposed the development and use of material flows indicators such as Direct Material Input (DMI) and Total Domestic Output (TDO). The analysis showed that, for the nations included in the study, several key findings emerged:

- Economic growth and an energy- and material-intensive lifestyle offset gains in efficiency and environmental management.
- Waste generation continued to increase.
- One-half to three-quarters of the annual amount of material inputs to the economy returned to the environment as wastes within the year.
- Carbon dioxide emissions from the use of energy materials (i.e., fuels) dominated outputs to the environment.
- In the United States, outputs for some individual hazardous materials declined or stabilized, but total output of hazardous materials continued to increase.

Sources: Robert U. Ayres and A.V. Kneese. 1969. "Production, Consumption and Externalities," *American Economic Review* (59):282–296; Emily Matthews et al. 2000, *The Weight of Nations: Materials Outflows from Industrial Economies.* (Washington, D.C.: World Resources Institute); Albert Adriannse et al. 1997. *Resource Flows: The Material Basis of Industrial Economies.* (Washington, D.C.: World Resources Institute).

By the last decade of the twentieth century, policymakers began to look for a next generation of environmental policy tools to overcome this fragmentation. These tools included setting priorities by using comparative risk analysis and encouraging pollution prevention through changes in design of products and processes. Some policy innovators focused on materials policy,[14] and researchers began to develop indicators of the flow of resources through the economy.

With international partners, WRI undertook an initiative in the late 1990s to develop indicators of *total* inputs and outputs of bulk commodities and resource-intensive activities related to material extraction and infrastructure development. (See Box 1.)

One outcome of the WRI work was the recognition that the scattered data on materials needed to be organized into physical accounts. In addition, it became clear that some types of data were very difficult to obtain. WRI's second report, released in 2000, concluded, "Physical accounts are urgently needed, because our knowledge of resource use and waste outputs is surprisingly limited."[15]

Strengthening this call, the U.S. National Academy of Sciences Committee on Material Flows of Natural Resources, Products, and

Residuals released a report in 2003 stressing the need for "a consistent Material Flows Accounting framework to integrate existing and future data."[16] At the international level, both the G-8 and the Organization for Economic Cooperation and Development (OECD) have recognized the need for more systematic monitoring of environmental quality by recommending the establishment of "economy-wide material flows accounts" and urging that "the usefulness of indicators derived from material flows accounting should be further explored."[17]

2

A USEFUL TOOL FOR ENVIRONMENTAL POLICYMAKING

So far MFAs are being used primarily to support indicators of bulk or aggregated material flows through national economies. This policy brief proposes developing more detailed accounts that can be used to support indicators at the levels of sectors and individual materials as well as for environmental policy decisions at strategic and operational levels. Whether the problem is indoor or outdoor air pollution, climate change, contaminated water, leaking waste sites, or disappearing habitat, materials flowing into, through, and out of the economy are likely to be the responsible agents. Organizing data by material flow[18] can thus serve as a useful framework for understanding the origins of environmental problems. This approach contrasts with first-generation environmental policies that primarily focused on a single stage of a life cycle. The new approach builds instead on existing efforts to move toward policies that consider the entire life cycle of materials in the economy and the natural environment.

Most data used in developing macro material flows indicators have been generated for use in economic reporting. Environmental data are used when available but U.S. emission data are fragmented and limited in what they cover, and waste data are generally not material-specific. One way to improve these data is to organize them by life cycle to highlight what is available, what is needed, and, thus, the location of gaps.

This policy brief complements earlier work that focused on the broader level of the national economy by proposing to organize output data systematically by life cycles. It draws on estimates from economic data (for metals, for example) and identifies emissions data to show what is now collected and to highlight what is now missing (data on production chemicals, for instance).

Current U.S. environmental laws regulating pollutants in air (the Clean Air Act), water (the Clean Water Act), and waste handling (the Resource Conservation and Recovery Act) provide an essential first line of environmental protection for the U.S. public. However, they focus on the *symptoms* of environmental problems. Each law typically applies regulatory standards to a single life cycle phase and one environmental medium (e.g., discharges to water during production), using a prescribed list of materials. Together, these laws, along with others governing workplace exposures (the Occupational Safety and Health Act) and public reporting on industrial emissions and wastes (the Emergency Planning and Coommunity Right to Know Act), cover about 1,100 individual pollutants. Less than one-third of these are addressed under two or more programs, and only 49 substances appear in all five laws.[19]

As a consequence, materials frequently slip through regulatory cracks. Some substances move off the regulatory radar screen as pollution or waste controls shift them to a part of the environment where they are not regulated. Because the existing laws focus almost entirely on the production and waste management phases, little information is available on outputs to the environment from the use and disposal of materials in consumer products. For the great majority of materials that are unregulated, data on outputs to the environment are usually unavailable or depend on rough estimates based on economic activities. Tracking the materials themselves directly addresses these deficiencies in the current system.

While the air, water, and waste laws dominate environmental policy, some strands of environmental legislation have long recognized the value of a material focus and a life-cycle approach. In 1976 Congress adopted the Toxic Substances Control Act (TSCA) to reduce unreasonable risk from toxic chemicals throughout their commercial life cycle. Under this law, EPA identified for the first time the number and amounts of industrial chemicals produced and imported into the United States. As of 2003, more than 76,000 chemicals were identified as used in commerce.[20]

The Pollution Prevention Act adopted by Congress in 1990 is similarly inspired by the life-cycle approach to environmental policy. The law encourages consideration of the entire life cycle flow of materials by stating a policy that pollution should be prevented or reduced at its source whenever feasible, with a secondary preference for recycling. Treatment and disposal are considered the least favorable options under this policy.[21] More recently, EPA has taken initial steps to identify and analyze the common origins of major environmental problems through programs such as the RCRA Vision project[22] and the Resource Conservation Challenge.[23] While the ambition is to develop strategies that would effectively address resource efficiency and minimize environmental releases, these programs largely remain in a planning phase.

Already public, standardized data about the amounts of toxic substances entering the environment at facilities have demonstrated their usefulness. Established by Congress in 1986, the Toxic Release Inventory (TRI) requires industrial facilities to report releases for about 650 chemicals to air, water, and land as well as transfers to waste facilities. Government, business, and environmental advocates use TRI data in developing and evaluating policy and in community negotiations related to individual facilities or regions.[24] The database can be searched by chemical, by facility, and by location, making it easy to set and track goals to improve environmental performance.[25] The data can also be aggregated to track trends. Nationally, for example, they show a 48 percent reduction in total onsite releases from facilities between 1988 and 2000. Transfers of waste offsite have increased slightly over the same period.[26] TRI shows the benefit of using a standard form to collect data on outputs, enter them into a database, and disseminate them widely. While a useful source of data for material flows accounts, TRI covers only a small portion of materials, and it focuses primarily on the production phase of the life cycle.

A comprehensive framework for tracking the *entire flow* of materials that enter and exit the economy remains absent. No set of accounts provides information about the inputs and outputs of a material over its entire life cycle in the national economy, or how one flow affects another. Without a framework and a set of accounts for organizing the data by life cycle, each attempt to address an environmental pollutant across the cycle requires a costly effort to locate and reorganize information from existing sources and to fill in the missing data. At the same time, such a framework and database are needed to support the development of strategic environmental indicators at the level of the national economy.

Economists regularly use indicators such as the gross domestic product (GDP) to measure the state of the economy as a whole. Such macroscopic indicators to track the state of the environment at the national level, however, remain elusive. Due to the many types of units used to monitor environmental quality (i.e., concentrations in air and water, amounts emitted, biological populations, etc.), environmental indicators typically defy aggregation. The majority of indicators used in EPA's *2003 Draft Report on the Environment* relate to releases of single substances to single parts of the environment or ambient measures for them.[27] Release data for regulated substances and ambient indicators are also used to comply with the Government Performance and Results Act that requires federal agencies to establish quantitative performance goals to measure the effectiveness of policies.

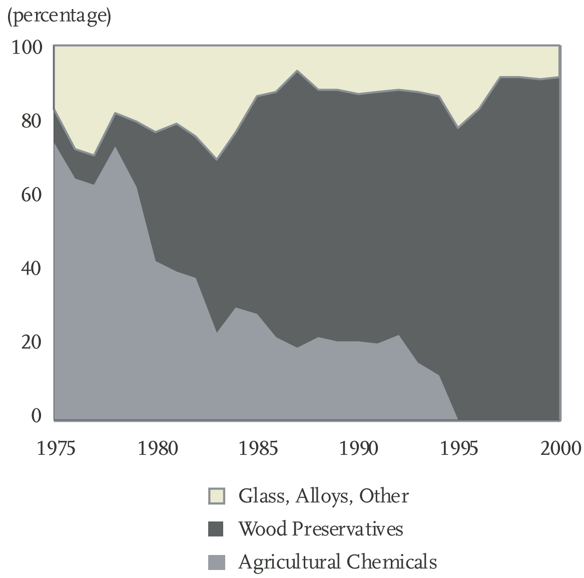
However, such measures frequently fail to fully capture broader progress or backsliding due to their narrow focus and are subject to variations due to unrelated factors such as changing industrial practice and even changing weather conditions. Indicators, such as the outputs of a class of hazardous materials to the environment, would complement more specific indicators by helping answer broader questions such as: Are we reducing the quantity and toxicity of persistent toxic materials entering the environment across the entire flow? Are consumer uses of hazardous materials increasing or decreasing? For what classes of materials should researchers be looking for substitutes? MFA indicators can be combined with ambient and other measures to enable government managers to set more inclusive targets and better track the effectiveness of environmental policies.

At the operational level, more detailed accounts can help identify the most effective points for policy intervention to increase the efficiency of the flow of materials and reduce the dispersion of hazardous materials to the environment. For example, MFAs support indicators of resource productivity that allow comparisons between different phases of the commercial life cycle for the same material flow (e.g., ratios of production waste to production, or outputs to uses) or between different flows (e.g., feed crops and meat production). These indicators offer insight into how the economic activity relates to the flow of materials into the environment.[28] Between 1970 and the mid-1990's, for example, the amount of residues recovered from lumber production rose 24 percent, indicating the increased flow of the residues to paper manufacture and energy recovery.[29]

Material flows data at the level of individual substances have already proven helpful in formulating national environmental policy. For example, over the past decade material flows analyses threw a spotlight on the flows of arsenic to pressure-treated lumber. A review of arsenic by end use in the U.S. economy shows a shift from use as a pesticide to use in a consumer product, pressure-treated lumber for residential and community structures. (See Figure 2.) When coupled with the investigation of the exposure pathways of arsenic from products into the environment, information about the flow of arsenic eventually led to EPA action in 2003 to limit residential and commercial uses of this product in the United States.[30] If such data were regularly available and reviewed, it could lead to earlier action. As new policies limit use, MFA data can help monitor their effectiveness.

Material flows data can also be helpful in using comparative risk assessment to set priorities. So far, comparative risk assessment has been used to set priorities among problems such as urban air pollution, pesticide residues in food, or habitat destruction. Because the sources of environmental problems frequently overlap in the flow of materials, solving a single problem at a time may transfer it elsewhere or ignore the opportunity to address several problems at the same time. As policymakers look for the origins of problems in the flow of a material, including associated flows, they can avoid transfers from one environmental medium to another and also identify opportunities to reduce multiple impacts. For example, the apparently separate problems of a Dead Zone in the Gulf of Mexico and climate change both turn out to be related to the flow of nitrogen from fertilizer use on farms. More efficient use of nitrogen fertilizer will limit the depletion of oxygen in the Gulf and reduce atmospheric emission of nitrous oxide.[31] Such changed agricultural practices can both improve water quality and protect the climate. Figure 3 shows the result of a material flows analysis of nitrogen, county by county, across the U.S. Mississippi basin. Such an analysis could be used to target locales where synthetic nitrogen fluxes are highest.

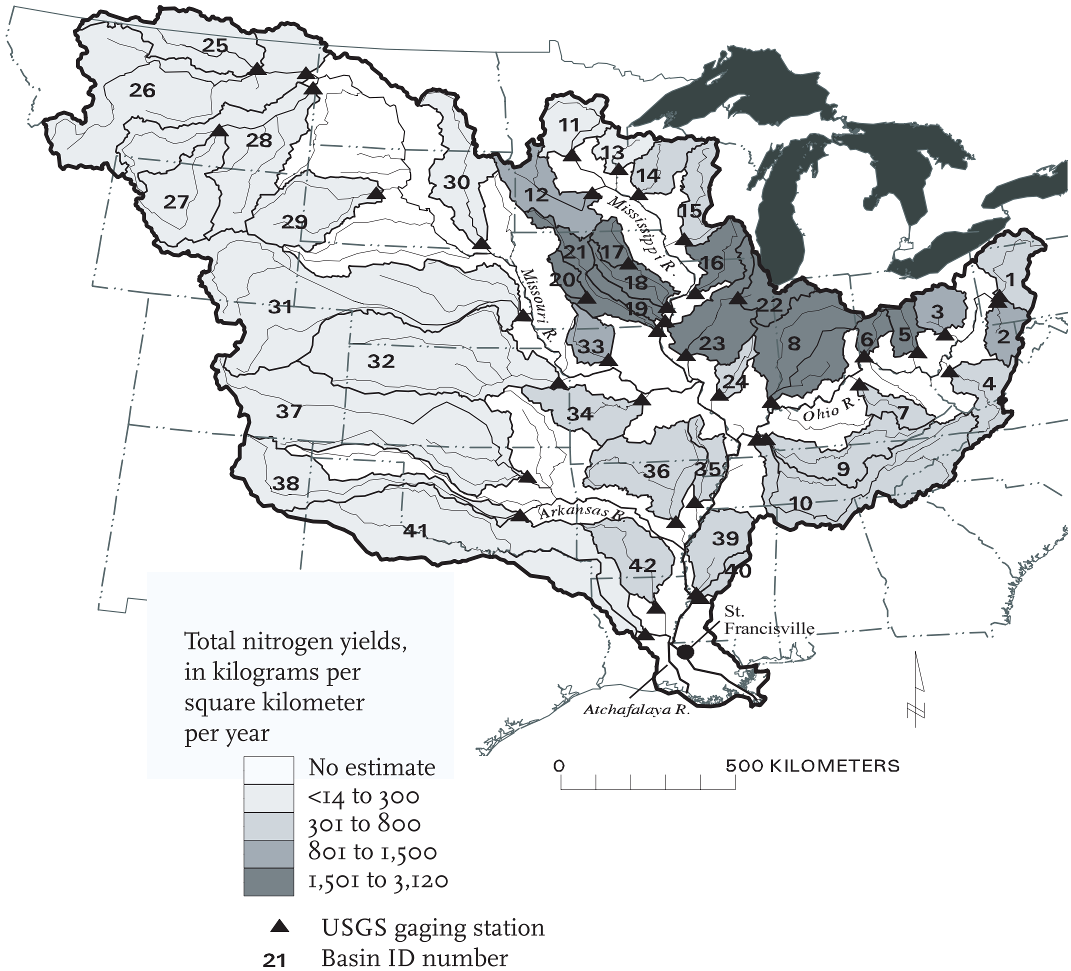
FIGURE 2 | **ARSENIC CONSUMPTION BY END USE IN THE UNITED STATES, 1975–2000**



Sources: U.S. Geological Survey. Mineral Commodity Summaries and Minerals Yearbook. Published annually. (Washington, DC: U.S. Geological Survey); WRI Material Flows Project.

When elevated levels of silver were found in the tissue of fish in San Francisco Bay, officials searched in vain for a missing large-point source as the origin. Using material flows analysis, university researchers eventually identified the many small dental offices and photographic labs as the sources.[32] Studies using life-cycle data are helping to identify the sources of mercury and cadmium pollution in the New York/New Jersey harbor from industrial emissions and consumer products and to suggest strategies for reducing them, such as targeted recycling.[33] On a wider scale, a recent USGS study found evidence of some 95 pharmaceuticals, hormones, and other organic wastewater contaminants in 80 percent

FIGURE 3 | **MATERIAL FLOWS IN THE MISSISSIPPI-ATCHAFALAYA RIVER BASIN, AVERAGE ANNUAL TOTAL NITROGEN YIELDS FROM 42 INTERIOR BASINS, 1980**

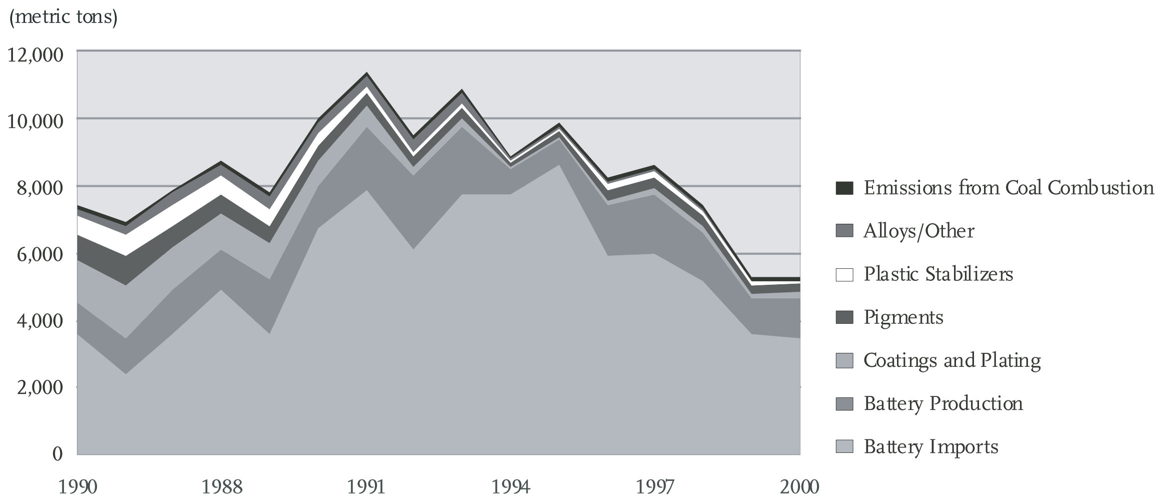


Source: Donald A. Goolsby et al. 1999. Nitrogen Flux and Sources in the Mississippi River Basin. (Denver, CO: U.S. Geological Survey).

of streams surveyed in 30 states.[34] WRI's 1997 and 2000 reports on U.S. material flows outputs suggest a possibility for the source: the quantities of medical chemicals released to the environment have doubled over the past 20 years.

Commercial radioisotopes provide another example of how MFAs can further desired policy objectives. Because of their association with national security, commercial power production, medicine, and other industries, radioisotopes fall under the purview of more than one government

FIGURE 4 | **ESTIMATED CADMIUM RELEASES IN THE UNITED STATES, 1975–2000**



Source: WRI Material Flows Project.

Note: Cadmium contained in batteries in imported finished goods is not included.

agency, making it difficult to track a material such as Cesium-137, which is used widely in the economy. Concerns over the disposition of Cesium-137 include fear of public exposures, contamination of metal scrap processing facilities, and national security.[35] MFAs are currently being developed to help monitor the flow of Cesium-137 and other radioisotopes and hold the promise of improved methods for tracking and licensing these materials by the federal government.

Representatives of local civic groups and experts in mining, economics, toxicology, public health, ecology, and law now enter the environmental debate using different, sometimes incomparable, language and tools. All would benefit from a vivid and consistent picture of the material flows involved, which would provide a basis for making public policy as well as commercial and household decisions. Effective presentation of data by end use, such as those on nitrogen sources or arsenic uses or cadmium releases, demonstrates how material flows data can be used to communicate with the public. (See Figure 4.)

Clearly, a basic set of material flows accounts offers the promise of advancing environmental policy at the strategic level of setting priorities, choosing targets, and tracking performance as well as at the operational level of finding the best leverage points for avoiding particular environmental releases. The accounts would also provide a common set of data to improve communication, both among experts and with the general public. The question remains how to establish a material flows accounting framework that draws on existing public and private data sources and provides useful indicators for government managers and the public.

3

FRAMEWORKS FOR MATERIAL FLOWS ACCOUNTING

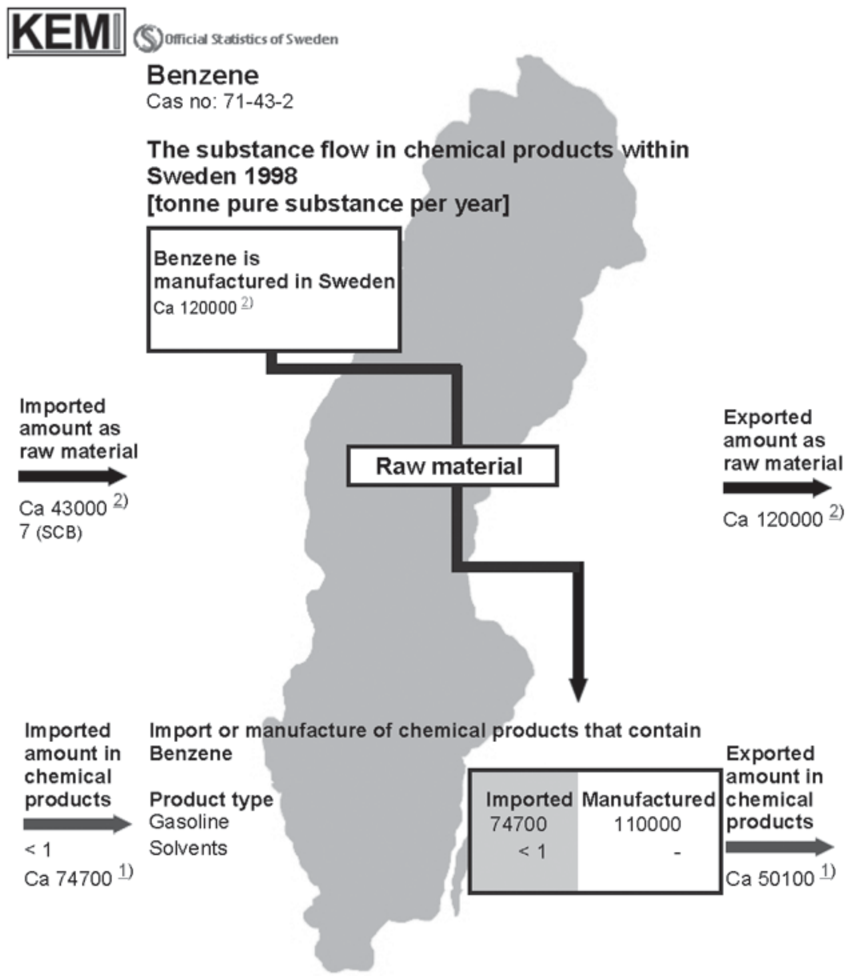
Aggregated national material flows accounts are becoming standard in the European Union (EU). The EU has published a methodological guide[36] and regularly publishes material flows indicators for EU countries.[37] These aggregated accounts provide indicators that are based on estimates of inputs to the economy of industrial minerals, fuels, construction materials, and agricultural products and of outputs of emissions and wastes to national environments. Such accounts treat the national economy essentially as a "black box." They focus on inputs and outputs but provide little detail on internal flows.

Physical input-output tables (PIOTs), in contrast, go a step beyond national aggregated MFAs in providing more detailed information on the structure of material flows within national economies, not just what goes in and comes out. PIOTs are modeled on national economic input-output tables that monitor the monetary flows among economic sectors to final consumers. PIOTs augment these detailed national economic accounts with data on the flows among sectors, consumers, and the natural environment, measured in units of the mass, or weight, of the materials. Both Germany[38] and Japan,[39] have introduced these tables as part of their national environmental statistical systems.

Product registries offer another approach to accounting for material flows. These registries have developed primarily in the Nordic countries to provide information for risk management and now constitute an integral part of their national environmental statistics. The SPIN database (Substances in Preparations in the Nordic Countries) provides nonconfidential data on the volumes of chemicals flowing into the economy and also identifies the economic sectors in which they are used, the type of products in which they are found, and whether they are used in consumer products.[40] The Swedish Product Register provides a national example. Begun in 1978, the register emerged from laws regulating hazardous chemicals. Companies report annually on the materials they have used that contribute to such human health effects as allergies, cancer, and birth defects. Using data from the product register and other economic data, the Swedish government publishes flow cards that offer data on the amount of a material that is imported, manufactured, and exported and on how it is used in the national economy.[41] (See Figure 5.)

Product registries have generated product-level data used to support more complete analysis of how materials enter the environment. One Swedish study found that the amounts of heavy metals going into products were over three times

FIGURE 5 | SWEDISH PRODUCT FLOW CARD FOR BENZENE FOR 1998



Source: Swedish National Chemicals Inspectorate, available at <http://www.kemi.se/kemstat/floden/_flodenbild/floden.cfm?id=249>.

larger than those emitted from the production facilities. With the exception of mercury, emissions during the production phase accounted for 3 percent or less of the potential outputs to the environment from products both during use and as waste at later stages in the flow.[42] A study by the California Air Resources Board also showed the importance of considering the use phase in its finding that consumer products emitted more volatile organic compounds during use than all the refineries and gasoline stations in the state.[43] These studies highlight the importance of including data about all phases of the commercial life cycle in MFAs. The failure of most existing environmental data frameworks to track materials during a product's use misses a major source of pollution and of waste to the environment.

In the United States, New Jersey[44] and Massachusetts[45] offer examples of a facility-level approach to collecting, managing, and disseminating materials data. These states are unusual in tracking the amount of listed chemicals going into products as well as the amounts released to air, water, and soil and transferred as waste. The Massachusetts data show that reporting companies that have collected data since 1990 steadily reduced the quantities of chemicals they used in the following decade, falling 45 percent by 2001. Onsite releases from the facilities fell by 92 percent, showing significant reductions in outputs of the listed chemicals during the manufacturing phase. Companies have found that they can reduce their environmental permitting, production, and waste management costs by taking such measures as reformulating products with non-toxic ingredients and recycling raw materials through the production process.[46]

While corporate environmental reports typically discuss compliance with laws on emissions and wastes, some reports have begun to offer information on the physical flows of materials, energy, and the resulting internal costs to the company.[47] Such reports are particularly prominent among Japanese companies, reflecting enhanced government attention to measures of material flows.

International standards for corporate material and energy flows reporting are also emerging.[48] The Eco-Management and Audit Scheme (EMAS) offers one example in which participating companies prepare public reports that include information about the amounts of materials, energy, and water they use. EMAS provides guidance on how to report on particular flows using physical units.[49] The Global Reporting Initiative (GRI),[50] an emerging global standard for corporate environmental and sustainability reporting, also offers general indicators of amounts of materials used in different categories as well as indicators for pollutant releases and waste.

A detailed protocol, such as the Greenhouse Gas Protocol,[51] is not yet available for organizing material flows data. Although public reporting for firms is generally voluntary, a few countries require their larger companies to prepare reports. Denmark,[52] for example, includes information on material input and output flows in its system of Green Accounts.

The variety of material flows accounting frameworks discussed here demonstrates the range of current approaches and their strengths and limitations in materials covered, level of detail, and methods of data collection and dissemination. Table 1 summarizes examples that indicate the status of material flows accounting.

Aggregated national MFAs provide indicators of the material intensity of whole economies. At the other end of the continuum, environmental management systems and reports provide data on material flows at the level of individual facilities and firms, data that can contribute to internal business decisions and allow for benchmarking performance across firms. The Nordic product registries and state tracking systems show one way to fill the data gaps, particularly for the product-use phase and to provide the public with information at the national level about chemicals found in consumer products.

TABLE 1 | SAMPLE FRAMEWORKS FOR MATERIAL FLOWS ACCOUNTING

Framework	Materials Covered	Types of Input and Output Data	System Boundaries	Data Collection Method	Data Accessibility
World Resources Institute (WRI)	160 commodities initially	Production, uses, imports, exports, and outputs across the life cycle	U.S. economy, U.S. environment	Government and trade association databases	Available for use in fall 2005
EUROSTAT [European Union Statistical Agency]	Several dozen aggregated and waste flows	Aggregated inputs and assorted wastes	National economies and EU-15	National statistical offices, third- party research institutes	Public database[1]
Center for Global Environmental Research, Japan	Major raw material trade categories	International trade focus	Japanese trade	UN trade dataset	Data available to the public[2]
Green Accounts, Denmark	Substances used in listed industrial activities	Amounts used in production of products or released as waste	Facility, company	Companies engaged in listed activities required to submit reports to government agency	May use index to protect confidential data
Product Register, Sweden	Flow cards for 200 high-volume chemicals	Imports, exports, and production amounts going into consumer use categories	Company reports aggregated at national level	Company data, reported on custom forms	Flow cards at national scale; some information on consumer uses in database[3]
Massachusetts Toxics Use Reduction Act	Chemicals listed in CERCLA and Toxic Release Inventory	Inventory and throughput data, including amount entering products	Facility data can be aggregated to state level	Annual report submitted by facilities meeting criteria	Data available by chemical, facility, and community[4]

Source: WRI Material Flows Project.

Notes:

1. See Wastebase, a database maintained by the European Topic Center on Resource and Waste management, at <http://waste.eionet.eu.int/wastebase>.

2. See <http://www-cger.nies.go.jp/>.

3. Sweden, Denmark, Finland, and Norway provide access to summary information from its product register about production volume by use at <http://www.spin2000.net/spin.html>. Flow cards can be found at <http://www.kmi.se/> Click on "databases" and then on "flow analyses."

4. See Toxics Use Reduction Institute at <http://www.turi.org>.

4

THE MATERIAL FLOWS DATABASE AND A MATERIAL FLOWS DATA SHEET

As a step toward a U.S. framework, WRI is developing an MFA database and associated protocols for collecting, analyzing, and presenting material flows data. The database systematically categorizes materials flowing through the U.S. economy, emphasizing transparency in documenting data sources and any assumptions made in estimating the flows. The database is designed to be built by a network of data providers and will eventually be available to the general public. The ultimate goal for this activity is to see that the periodic compilation and dissemination of U.S. material flows accounts shifts from civil society to become an established function of the federal government. A description of the pilot MFA database follows.

Materials Coverage

The MFA database is designed to cover the physical resources entering the economy and follow them as they undergo successive physical and chemical transformations as they move through the material life cycle. The database is structured around a list of the primary commodities that drive the U.S. economy, covering five principal resource sectors: agriculture, forestry, non-renewable organic materials (e.g., fossil fuels), metals, and minerals. The database is designed to cover the entire chain of materials that flow through the U.S. industrial economy, from primary inputs, or feedstocks, such as petroleum, salt, and industrial roundwood, to processed materials such as benzene, gasoline, chlorine, and lumber.

To complement this initial collection of materials, the report explores five chemicals on the list of Waste Minimization Priority Chemicals compiled by EPA's Office of Solid Waste. The purpose of including these chemicals is to test the utility of the database for substances of specific concern to human or ecological health. Over time the data coverage can expand to more fully capture the material process chain and to incorporate additional hazardous materials based on criteria such as high volume production, persistence, tendency to bioaccumulate, or rapid dissipation into the environment.

The Material Flows Data Sheet: A Template for Entering Data into the Accounts

Material flows data sheets (MFDSs) offer a way to organize data on individual materials and provide a standard template for material flows data to be entered into a database. The core set of data elements contained in the MFDS includes information describing the material's 1) context in the national economy, 2) inputs to the economy, including raw material supplies from all sources, and 3) outputs to the environment, including processing wastes and outputs resulting from use. All values are uniformly denominated in mass units.

Context

To establish the context for material flows, each MFDS includes information listing the name of the commodity and the resource sector to which it belongs, for example, agriculture, energy, forestry, or metals and minerals. The level of material use in the chain of processing can also be included. For example, copper could be classified as copper ore (level 1), copper metal (level 2), copper pipe (level 3), and so on.

In addition, the MFDS identifies the industrial and consumer codes associated with a material flow, such as the North American Industry Classification System used by the Census Bureau, the industrial function category and the commercial/consumer product category codes now required for reporting under TSCA[53]; and the chemical abstract service number when applicable.[54] Registry numbers can also be included from EPA's Envirofacts Master Chemical Integrator (EMCI), which provides information about a given material across different government regulations.[55] Together, these codes allow for linking the data associated with a particular material flow with other economic and environmental data. The use of international standards will allow for more precise comparison with indicators developed in other countries and used by international organizations such as the World Bank.[56]

Because much of the interest in material flows stems from the dependencies that exist between flows in the economy, MFDSs formalize these relationships using a field to record associated flows. For example, associated flows occur in the case of zinc and cadmium. While cadmium is not mined as a primary ore by itself, its occurrence in ores mined for zinc allows it to be extracted during the smelting and refining processes. The associated cadmium flow would be noted on the zinc data sheet.

Inputs

Input data for materials covered by MFDSs include the quantity of production, secondary production (production from pre- and post-consumer waste), by-product production (production as a by-product of another industrial process), imports, exports (a negative input), and changes in inventory. Included under inputs are the amounts of a material imported or exported as a component of finished goods (e.g., cadmium in nickel-cadmium batteries in imported or exported electronic devices).

Outputs

The section titled outputs from production on MFDSs reports the amount of materials entering the natural environment from the production of final products. This section provides details on the outputs generated as extractive wastes, processing wastes, and manufacturing wastes from domestic and foreign sources.

MFDSs also show the uses of a commodity in the economy to identify, for each use, the resulting outputs to the environment and the quantity of materials going to recycling (a negative output). Incidental outputs represent material outputs to the environment that are not of the same material as that being measured (e.g., mercury emissions would be an incidental output from coal used for energy production).

Hidden Flows

Some flows associated with the extraction of a commodity (e.g., overburden removal), processing (e.g., concentrator tailings), and refining (e.g., smelter wastes) are termed hidden flows. They are considered "hidden" because they do not enter the dollar economy and are generally simply disposed of. All of these flows, with the exception of losses during recycling, occur prior to the commodity entering the use phase of the materials cycle. Many are very harmful to the environment. On the material flows data sheet, all the hidden flows associated with production are identified with an hf. Releases of wastes to the environment that occur during use or post-use are considered outputs.

Where two commodities, such as zinc and cadmium, are contained in an extracted metal ore, the extraction waste and the removed nonmetal components of the ore are charged to the primary commodity, in this case zinc. Releases of cadmium, the secondary metal, during processing and refining are considered units of that commodity. All non-mineralized wastes in the ore are accounted for on the primary commodity data sheet, in this case, that of zinc. Depending on where the activity takes place, these flows may result in either domestic or foreign releases to the environment, many of which cause much harm.

Flow Descriptors

A column called flow descriptors is included in the data sheet to provide a space for additional information on specific flows. In the cadmium example, the nature of each of the uses of cadmium in the economy has been indicated, along with a notation that the extractive wastes were assigned to the zinc data sheet.

Environmental Descriptors

Because materials vary greatly in their properties, the number of tons alone does not effectively convey their impact on the environment. An initial rudimentary characterization method uses three environmental descriptors that relate each flow to its potential for environmental impact. This broad characterization scheme suggests an addition, not a replacement, to the detailed assessments performed by agencies such as EPA.

Most generally, the environmental impact from a material flow depends on how it enters the environment, its inherent potential for harm, and the amount of time that the material resides in the economy. Three environmental descriptors, mode of release (M), quality (Q), and velocity (V), provide an approximate weighting of the impact of flows. The mode of release describes the physical form (gas, liquid, or solid) of the material and its freedom of movement in the environment. Quality describes the potential for environmental damage inherent in the material, ranging from materials that rapidly biodegrade to those known as toxicological threats. The velocity of a flow describes the average time that the material resides in the commercial economy and is essential for estimating the time before a material is dissipated or enters the waste stream.

Decades of effort by EPA and others have resulted in a wide range of environmental descriptors to distinguish substances by their hazardous properties and by their potential for a negative impact on human health and the environment.[57] One set of descriptors under development at EPA, the Tool for the Reduction and Assessment of Chemical and other Environmental Impacts (TRACI),[58] could be used in the future to more precisely link data from material flows accounts to impacts. Such links would be made by using impact coefficients. Potential areas covered by TRACI include global warming, acidification, eutrophication, photochemical smog, human health, ecotoxicity, fossil fuel use, land use, and water use. TRACI is designed to work independently of site-specific knowledge but has the capacity to provide more precise results given more detailed data. The material flows database will eventually be able to link to environmental impact coefficients and geographic markers to enable analysts to localize problems and target solutions.

Data Sources and Notes

To ensure transparency and the means to check data quality, full reference to the data source is included in MFDSs. In addition, the notes section records the assumptions, conversion factors, and calculations used to estimate flows. Table 2 lists all the elements that should be included in a material flows data sheet.

Collectively, these elements provide sufficient data to describe the flow of a material through the economy and offer a way of relating that flow to other materials. Figure 6 shows a sample material flows data sheet filled out for cadmium.

TABLE 2 | CORE DATA ELEMENTS IN A MATERIAL FLOWS DATA SHEET

Basic Information
Commodity
Resource Sector
Level of Processing
Industrial/Consumer Codes
Data Sources
Associated Flows
Flow Descriptors
Inputs
Production
Secondary Production
By-Product Production
Changes in Inventory
Imports/Exports (raw materials)
Imports/Exports (finished goods)
Reported Use
Outputs from Production
Extractive Wastes
Processing Wastes
Manufacturing Wastes
Uses
Uses (listed as 1, 2, 3, 4, etc.)
Post-production Outputs
Outputs from Each Use
Environmental Descriptors
Incidental Outputs

Source: WRI Material Flows Project.

Data Sources

The data found in MFAs draw from a broad array of environmental, resource, and economic sources. The numbers themselves may have been reported, recently measured, or the estimates of experts. Regardless of the units used in the primary data sources, all data are converted to mass units, which provide the currency for MFAs.

FIGURE 6 | **MATERIAL FLOWS DATA SHEET FOR CADMIUM** *(all data are in metric tons)*

Commodity Cadmium
Level of Processing 2
Resource Sector Metal
Economic Sector (NAICS) 21

	FLOW	ASSOCIATED FLOWS	ENVIRONMENTAL DESCRIPTORS			FLOW DESCRIPTORS	1975	1976	1999	2000	DATA SOURCES	NOTES
INPUTS	Input - Production						1,990	2,050	1,190	1,890	MCS	
	Input - Secondary Production (old scrap)						0	0	275	275	MCS	Includes Ni-Cd batteries, some alloys, and electric arc dust. USGS specialist estimates
	Input - By-product Production											
	Input - Imports						2,600	3,300	294	425	MCS	
	Input - Changes in Inventory						0	0	550	319	MCS	
	Input - Exports						180	230	20	312	MCS	
	Imports (finished goods)					Batteries, imported			3,600	3,450	NYAS	Estimate based on volume of imports
	Exports (finished goods)											
	Reported Use (if available)					Apparent use	3,100	5,400	1,850	2,010	MCS	
			M	Q	V							
PROCESS WASTES	Hf-Extractive-Waste - Domestic					Assigned to zinc	0	0	0	0		
	Hf-Processing-Waste - Domestic	Zinc processing				Zinc concentration	620	1,080	370	402	USGS estimate	20% reports to zinc tailings
	Hf-Processing-Waste - Domestic	Zinc processing				Zinc smelting	310	540	185	201	USGS estimate	10% reports to zinc smelter dust and slag
	Hf-Manufacturing-Waste - Domestic					Cadmium			825	386	TRI Explorer	
	Hf-Manufacturing-Waste - Domestic					Cadmium compounds			3,842	3,965	TRI Explorer	
	Hf-Extractive-Waste - Foreign											
	Hf-Processing-Waste - Foreign	Zinc processing				Zinc concentration	520	660	59	85		
	Hf-Processing-Waste - Foreign	Zinc processing				Zinc smelting	260	330	29	43		
	Hf-Manufacturing-Waste - Foreign											
	Hf-Domestic recycling						0	0	3	3		Assume 1% of total
USES	Use 1					Coatings and plating	1,550	2,700	148	161		
	Use 2					Batteries, domestic	310	540	1,332	1,508	MCS, 1997	
	Use 3					Pigments	780	1,190	241	241		
	Use 4					Plastic stabilizers	160	270	111	80		
	Use 5					Alloys /other	310	700	19	20		
OUTPUTS	Output - Use 1		1	5	2	Coatings and plating	1,550	2,700	148	161		
	Output - Use 2		1	5	2	Batteries, domestic	310	540	1,057	1,233		
	Output - Use 3		1	5	2	Pigments	780	1,190	241	241		
	Output - Use 4		1	5	2	Plastic stabilizers	160	270	111	80		
	Output - Use 5		1	5	2	Alloys /other	310	700	19	20		
	Output - Incidental 1	Coal combustion	5	4	1	Emissions from coal combustion	70	80	120	120		
	Recycling - Use 2					Batteries	0	0	275	275	USEPA	Only large industrial NiCds are recycled

Note: Hf =Hidden Flow
Source: WRI Material Flows Project.

Most generally, resource inputs, including trade data, are provided by statistical offices in governmental agencies such as the Mineral Information Team at the U.S. Geological Survey (USGS), the Energy Information Administration at the U.S. Department of Energy (DOE), and the Forest Products Laboratory and National Agricultural Statistics Service at the U.S. Department of Agriculture (USDA). Economic data collected by various offices at the U.S. Department of Commerce offer numbers in physical units on production and trade for some processed materials and manufactured goods. However, data on manufactured goods are most often given in dollar figures and typically do not specify material composition. As a result, product data generally rely on conversions from monetary data or expert estimates.

Data on synthetic organic chemicals (SOCs) come from government offices or trade associations and independent research institutes that serve the private sector. At the level of primary and secondary feedstocks to the chemicals industry, the Energy Information Administration produces detailed data on primary production of petroleum products and petrochemical feedstocks at U.S. refineries.[59] The challenge to obtaining these data comes only in part from the proprietary nature of much of the information. The challenge to organizing them derives from the fact that, unlike metals, organic chemicals undergo transformations during processing that change their chemical nature and can be the result of different synthesis pathways.

For industrial chemicals farther down the process chain, detailed production data are collected, in principle, under the TSCA inventory of chemicals in commerce. However, these data are given in ranges that span orders of magnitude and thus provide only upper and lower bounds for data values. Furthermore, a large portion of the chemical data collected under TSCA is considered confidential business information and as such is not available to the public. In the future, data collected under TSCA is supposed to provide more detailed information on chemical production volumes classified by industrial function and commercial/consumer product categories.[60]

The Census Bureau[61] and the International Trade Commission[62] at the U.S. Department of Commerce have traditionally collected information on domestic and foreign chemical shipments. However, this data collection function was significantly curtailed in the mid-1990s.[63] Proprietary considerations also prevent publication from private data sources that provide some of the most comprehensive data collections for synthetic organic chemicals. For example, trade associations such as the National Petroleum Refiners Association and independent research institutes such as SRI International offer data for a price, but explicitly prohibit their republication. In sum, the scarcity of publicly available data for these chemicals becomes rapidly evident as one moves up the value chain from primary feedstocks to specialty chemicals.

The USDA generates data on pesticide use that can be harvested from the Agriculture Chemical Use Database.[64] For inorganic chemicals, data obtained from USGS publications[65] and commodity specialists complement other sources to provide information on production, recycling, trade, and uses in the economy. Secondary data sources can also be useful for locating material flows data, such as the Toxicological Profiles prepared by the Agency for Toxic Substances and Disease Registry at the Centers for Disease Control and Prevention.

Obtaining material-specific data on outputs presents an even more formidable challenge. Many of the outputs to the environment occur during phases of the life cycle not covered by existing environmental data systems.[66] EPA waste data only rarely contain material-specific information. Even waste data without any material-specific detail can be hard to come by. For example, the most recent data set for nonhazardous industrial wastes at the national level date back to the mid-1980s. For heavy metals and SOCs, the TRI provides the most comprehensive data set available, though it is limited in sources, number of substances, and life cycle phases covered. Emissions databases and government reports on wastes from coal mining and oil and gas exploration provide essential data on extraction wastes. In the latter case, specialists with expert knowledge of production practices involved must estimate values for waste and release data.

Technical reports and pools of expertise scattered across the federal government provide useful information for constructing accounts. For instance, multiple offices in EPA and DOE compile technical reports that can be used for determining the mass of the materials that constitute the inputs to and outputs from industrial processes. Missing data can be estimated, based on the data that are available for other substances (e.g., precursors and derivatives) and on other phases of the material's life cycle. Knowing the ratio of chemical feedstocks necessary as inputs allows for deducing the use of these feedstocks by examining the outputs of production. For example, the reported amounts of tire production offer information relevant to the tire's main components such as synthetic rubber and carbon black.[67] Ayres provides numerous examples of deducing material flows using auxiliary data and technical process information.[68] Table 3 shows a representative, though not exhaustive, list of data sources arranged according to life cycle phase.

SHARING MATERIAL FLOWS DATA

Integrating material flows data from public and private statistical offices requires engaging commodity specialists across departments as well as representatives from industry trade associations. As a step toward formalizing the MFA network, WRI suggests the development of a remote database in the form of an Extranet for sharing material flows data. Requiring a password for entry, the Extranet would allow members of the network to enter material flows data relevant to their area of technical expertise and perform analyses based on any or all of the data residing in the database. As the network grows, the standards used for data entry would undergo continuing revision, with the associated development of tools to analyze the data.

Such an extensive database, which would enable governmental agencies and private sources to share data using a compatible format, should catalyze the development of uniform data standards, templates, and data-sharing protocols among the contributors, leading to regular compilation and dissemination of U.S. MFAs, including detailed sub-accounts. Such an ambitious and extremely useful project should be a function of the federal government. As a part of that process, data on substances that are priorities due to ecological or human health concerns could be added to the database, which now focuses on major commodities.

TABLE 3 | **SELECTED SOURCES OF MATERIAL FLOWS DATA BY LIFE CYCLE PHASE**

Agency	Office	Sector	Raw Material Supply	Production	Use	Disposal
U.S. Geological Survey	Minerals Resources Program	Minerals, Metals	Waste Estimates from Mining by Experts	Mineral Commodity Summaries[1]	Mineral Commodity Summaries	
	Energy Resources Program	Energy	Produced Waters Database[2]			
U.S. Environmental Protection Agency	Air and Radiation	Hazardous Substances		National Toxics Inventory[3]		National Toxics Inventory
	Solid Waste					Biennial Reporting Survey[4], Municipal Solid Waste Reports[5]
	Environmental Information					Toxics Release Inventory[6]
	Prevention, Pesticides and Toxic Substances			TSCA Chemical Substances Inventory[7]	Inventory Update Rule[8]	
U.S. Department of Agriculture	National Agricultural Statistics Service	Agriculture, Hazardous Substances	Agricultural Statistics Database[9]		Agriculture Chemical Use Database[10]	
	Forest Service	Forest Products	Resource Planning Assessment[11]	Annual Statistics for Forest Products[12]	Annual Statistics for Forest Products	
U.S. Department of Energy	Energy Information Administration	Energy, Hazardous Substances	Coal Mining Waste Estimates by Experts	Annual Energy Review[13]	Manufacturing Energy Consumption Survey[14]	
	CO2 Info. Analysis Center					CO2 Emissions from Fossil-Fuel Consumption [15]
	Office of Industrial Technology			Technical Reports	Technical Reports	
U.S. Department of Commerce	Census Bureau	Hazardous Substances, Minerals, Metals		Materials Summary	Materials Summary[16]	
U.S. Dept. of Transportation	Bureau of Transportation Statistics	Hazardous Substances, Minerals, Metals				

TABLE 3 | **CONTINUED**

Agency	Office	Sector	Raw Material Supply	Production	Use	Disposal
American Chemical Society	Statistical Division	Petro-chemicals, Hazardous Substances		Annual Production Surveys[17]		
American Chemistry Council		Petro-chemicals, Hazardous Substances		Annual Guide to the Business of Chemistry[18]	Annual Guide to the Business of Chemistry	
National Petrochemical and Refiners Association	Petrochemical Statistics			Selected Petrochemical Statistics	Selected Petrochemical Statistics	

Source: WRI Material Flows Project

Notes

1. U.S. Geological Survey. Mineral Commodity Summaries. Available at <http://minerals.usgs.gov/minerals/pubs/mcs/>.
2. U.S. Geological Survey, Central Energy Data Management. *Produced Waters Database.* Available at <http://energy.cr.usgs.gov/prov/prodwat/>.
3. National Transportation Library. *National Toxics Inventory*. Available at <http://ntl.bts.gov/card_view.cfm?docid=12145>.
4. U.S. Environmental Protection Agency, Biennial Reporting System. Available at <http://www.epa.gov/enviro/html/cerclis/cerclis_overview.html>.
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15. T.J. Blasing et al. 2003. "Estimates of monthly carbon dioxide emissions and associated 13C/12C values from fossil-fuel consumption in the U.S.A." *Trends: A Compendium of Data on Global Change.* (Oak Ridge, TN: U.S. Department of Energy, Oak Ridge National Laboratory, Carbon Dioxide Information Analysis Center) Available at <http://cdiac.esd.ornl.gov/trends/emis_mon/emis_mon_co2.html>.
16. U.S. Department of Commerce, Economics and Statistics Administration. 2001. Economic Census Manufacturing Subject Series. *Material Summary, 1997.* U.S. Census Bureau Report no. EC97M31S-MS.
17. American Chemical Society. Annual. "US Chemicals Production, Facts & Figures," *Chemical and Engineering News.* For example, see *Chemical and Engineering News*, June 25, 2001, pp. 44-51.
18. American Chemistry Council. Annual. *Guide to the Business of Chemistry.*

5

CASE STUDIES: EXAMINING FIVE HAZARDOUS SUBSTANCES

In the mid-1990s, using 1991 as a base year, the EPA Waste Minimization Program set a goal of reducing by half the occurrence of 30 priority chemicals in hazardous waste by 2005.[69] The chemicals were chosen because they are persistent, bioacummulative, and toxic. They are frequently found in both hazardous waste and the environment. The goal was reached in 2001.

Using an expanded list of priority chemicals, the National Partnership for Environmental Priorities now plans to work toward a new goal for 2008.[70] Using MFAs offers a way to complement the hazardous waste reduction goal by also looking at opportunities for reductions at other stages of the commercial life cycle, including, for example, releases to air and water during production and transfers of products containing hazardous substances to nonhazardous waste landfills.

WRI selected one of the priority chemicals to put into a material flows data sheet, Cadmium, and studied four others, Hexachlorobenzene (HCB), Naphthalene, Pendimethalin, and Trifluralin. These materials were chosen to include a range of material types and uses. (See Table 4.) Data for related inputs and outputs along its commercial life cycle were sought from EPA as well as other sources inside and outside the federal government to examine the feasibility of gathering the necessary data to evaluate the utility of the MFA framework for shaping policy decisions.

Synthetic organic chemicals and metals constitute the main categories of materials included in the original waste minimization priority chemicals list. Data for cadmium were relatively easy to obtain from sources across the federal government, particularly the USGS. The MFDS for cadmium (see Figure 6) shows a continuing decline in cadmium metal imports and confirms the shift in domestic uses from steel plating to batteries. The data also show that imports of finished goods containing cadmium batteries compensate for the decline in imports of cadmium metal.[71] This flow of cadmium batteries in imported electronic products will eventually enter the waste stream. Concern about cadmium batteries entering landfills gave rise to state laws that were followed in 1996 by federal legislation requiring that batteries be labeled and made easy to remove.[72] Material flows accounts could provide the means for tracking the effectiveness of such policies.

Two of the SOCs selected, Pendimethalin and Trifluralin, are produced specifically for use as pesticides. Organic pesticides have displaced many of the heavy metals, such as arsenic and

TABLE 4 | PROPERTIES FOR FIVE WASTE MINIMIZATION PRIORITY CHEMICALS

Priority Chemical	Material Type	Inputs	Potential Health/ Ecological Effects	Primary Use(s)
Cadmium	Metal	By-product from zinc mining, secondary production, imports	Carcinogenic, Linked to respiratory and renal damage	Batteries, plastics additives, metal plating
Hexachlorobenzene	Synthetic Organic Chemical	By-product from production and combustion of chlorinated chemicals	Carcinogenic, mutagenic, potential damage to liver, thyroid, nervous system, bones, kidneys, blood, and immune and endocrine systems	No commercial uses
Naphthalene	Synthetic Organic Chemical	By-product from coke production and petroleum refining	Possible carcinogen, damages or destroys red blood cells	Phthalic anhydride, mothballs
Pendimethalin	Synthetic Organic Chemical	Pesticide manufacture	Mild irritant to skin and lungs, highly toxic to fish and aquatic invertebrates	Crop protection
Trifluralin	Synthetic Organic Chemical	Pesticide manufacture	Moderately toxic to humans, toxic to fish, other aquatic organisms, and earthworms	Crop protection

Source: Agency for Toxic Substances and Disease Registry. Toxicological Profiles Series. Available at <http://www.atsdr.cdc.gov/toxprofiles/>.

mercury, which were once the stock-in-trade of agricultural pest control. Between 1980 and 1999, total U.S. consumption of insecticides fell 30 percent. Over the same period, the market share of insecticides made from SOCs grew to capture 25 percent more of the remaining insecticide market.[73]

For the years 1990–2000, both EPA and USDA data show a peaking in Pendimethalin production around the mid-1990s. Production data for Trifluralin show fluctuations over the decade, perhaps reflecting crop rotation patterns. TRI reporting thresholds for both priority substances were lowered in the year 2000 to 100 pounds annually. This change in threshold resulted in a nearly fourfold increase in reported Pendimethalin wastes but only a 40 percent rise for Trifluralin wastes. This difference in sensitivity to threshold requirements indicates that more facilities use Pendimethalin and in smaller amounts than those reporting Trifluralin use, suggesting different policy approaches.

HCB and naphthalene are both generated as by-products of other industrial activities. Data for the United States show that U.S. commercial production of HCB ended by the late 1970s. Thus, continuing emissions of HCB result from unwanted or by-product emissions. Like dioxins, HCB derives from chemical processes involving the manufacture of chlorinated chemicals or the combustion of products containing them. Because deliberate production has ceased, comprehensive HCB monitoring requires tracking variables such as the PVC content of incinerated municipal waste and emissions from the electrolysis of magnesium chloride ($MgCl^{2}$) for magnesium metal production.[74] While in principle the amounts of HCB generated by these activities can at least be estimated, the amounts remain undocumented and therefore unknown.

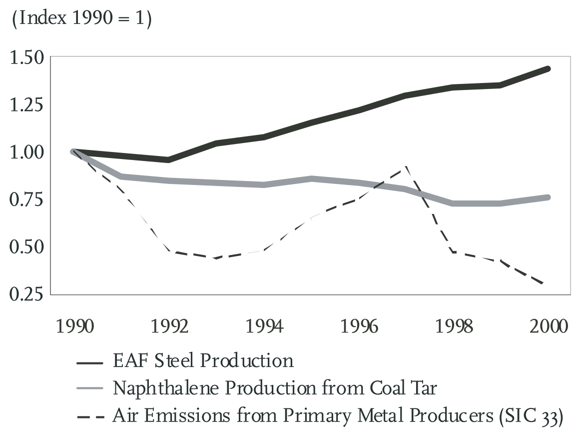
Naphthalene is a by-product from the processing of coal to coke for steel production as well as petroleum refining. Using data on coke production, along with technical data on the yield of naphthalene from the coking process, allows for determining naphthalene production from coke. No publicly available data were found on naphthalene production at petroleum refineries.

A downward trend in coke production over the last decades has directly led to significant reductions in naphthalene production and emissions from this source. Driving this change in coke consumption is the growth of electric arc furnace (EAF) steel production that relies on scrap metal inputs and thus avoids the need for coke used to process virgin iron ore. TRI data show that releases of naphthalene from primary metals producers fell by half from 1988 to 2000. Figure 7 shows the correlation between increased scrap steel recovery for EAF production and less hazardous material released into the environment. The rapid rise and fall in air emissions during the mid-1990s may reflect increased monitoring of coke ovens as a result of stricter regulations on benzene, another coke by-product. While the wastes generated during EAF steel production are also considered hazardous, several processors in the United States and abroad have developed processes for recovering metals, such as iron and zinc, from EAF dusts.

Phthalic anhydride, used for plasticizers in synthetic resins as a precursor for organic dyes and in the synthesis of primary amines and organic acids, accounted for more than half of naphthalene consumption in the early 1990s. Current trends point to a reduction in the production of naphthalene, possibly because of greater reliance on o-Xylene from petroleum refineries as the primary feedstock for phthalic anhydride. Other products made from naphthalene include mothballs, which generally account for less than 10 percent of naphthalene production.[75]

The leverage to reduce naphthalene emissions will come from reduced demand for coke in primary steel production and from decreased demand at refineries due to increased use of other feedstocks for phthalic anhydride production plus new resin and dye formulations that do not require phthalic anhydride. New ways of

FIGURE 7 **NAPHTHALENE PRODUCTION FROM COKE AND FROM EAF STEEL PRODUCTION AND TRI AIR EMISSIONS FROM THE PRIMARY METALS SECTOR (SIC 33), 1990–2000**



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keeping moths out of the closet (e.g., inedible clothes) will be needed to reduce naphthalene demand for mothballs.

WRI's analysis of these five chemicals validates the concern over lack of publicly available data on synthetic organic chemicals. However, the analysis did reveal some of the dependencies between material flows and the links between usage trends for materials. Aggregated TRI data show an overall downward trend in air emissions of napthalene averaging 62 percent from 1990 to 2000, which may indicate the use of more efficient industrial practices and a likely reduction in occupational and community exposure. Data on other release and waste transfers present a more mixed picture. Still largely unknown are the amounts used in products, amounts going to nonhazardous waste disposal, and amounts going into capital stock, even though these areas may comprise the main sources of outputs of these hazardous substances into the environment.

6

NEXT STEPS IN ESTABLISHING U.S. MATERIAL FLOWS ACCOUNTS

Past initiatives have demonstrated the feasibility of establishing material flows accounts and using them to establish indicators of material input and output at the level of national economies. Japan and several countries in the European Union have committed to variants of this approach, and efforts to refine the methodology are underway. At the same time, earlier work notes the importance of developing more detailed accounts for specific substances and for material categories.[76] The accounting framework proposed in this policy brief offers the opportunity to move toward standard, disaggregated accounts in the United States and in any other country interested in adopting the MFA approach.

The next steps towards institutionalizing material flows accounts in the United States involve three tasks: 1) Develop a network of resource, environmental, and economic data providers—including government information and statistical offices—to expand materials coverage and improve the protocols for entering and managing the data; 2) Identify the user community and evaluate methods for presenting material flows data that are policy relevant and accessible to the public; and 3) Convene a broad-based partnership of data providers and users to take the lead in institutionalizing material flows accounts, a process that is likely to require a congressional mandate.

TASK 1: DEVELOP A DATA PROVIDER NETWORK

A network of data providers would lead in the development of standard protocols for entering material flows data with data stored in a remote database—an MFA Extranet. The proposed Extranet would connect experts in economic, resource, and environmental agencies, enabling them to enter their own data and to view data entered by their colleagues. Additional data providers, from trade associations and nongovernmental groups with data, would also need to be closely involved.

Individual governmental agencies might agree to lead or co-lead multi-stakeholder groups that would take on different tasks. EPA's Office of Environmental Information is a logical choice to convene a group to propose how MFAs can most effectively draw on and complement EPA registries of environmental information. The USGS, DOE, and USDA could coordinate and improve existing commodity time series data with more detailed data on the uses of materials in the economy and the wastes associated with production. Agencies like USGS could coordinate expertise in geology, geography, hydrology, and biology to develop standards for geographical information on material flows and to deepen understanding of the relationship between material flows and impacts on the natural environment. The White House Council on Environmental Quality might address presentation and dissemination of the data through its work on environmental indicators.

To extend coverage of the database, data providers could join users to decide priorities for materials to add. Possible criteria for selecting additional materials could include:

- Materials used in very large quantities for housing, transport, energy, or agriculture;
- Materials, especially chemicals, that are persistent and bioaccumulative;
- Materials in consumer products that dissipate during use;
- Materials identified through environmental monitoring programs.

The group might examine the possibility of adding materials from specific lists. EPA's priority chemicals list is one. Others include persistent organic pollutants listed under the Stockholm Convention,[77] the list of chemicals being produced in large volumes being tested under an OECD program,[78] or the chemicals found on the U.S. national priorities list of hazardous waste sites.[79]

TASK 2: EVALUATE METHODS FOR USING AND PRESENTING MATERIAL FLOWS DATA

Many governmental agencies at local, state, and national levels are already developing environmental indicators. Government managers are experimenting with ways to use MFA data to help with evaluation and policymaking. Nongovernmental groups are also developing ways to look at and present the data. For instance, the environmental group INFORM provides information on persistent, bioaccumulative, and toxic substances entering the economy in industrial and consumer products in order to promote purchasing practices that prevent pollution.[80]

Examples of uses that might be explored by material flows users include ongoing initiatives as well as such new efforts as:

- Selecting targets for green chemistry projects to design substitutes for products that are major sources of dissipative uses;[81]
- Tracking changes in waste reduction and recycling using a basket of substances; and
- Using a basket of substances to track changes in the characteristics of the materials that Americans use. Are they increasingly biodegradable, for example?[82]

To encourage broader public use of MFAs, the data need to be disseminated widely in an easily understood form. While the TRI data are easily available to anyone to analyze, most people gain knowledge through reports and presentations by government agencies, nongovernmental groups, and businesses or through media coverage. Users of material flows data, including government agencies, nongovernmental organizations, and businesses, can be encouraged to work together to experiment and evaluate different ways of using and presenting MFA data. For example, in the 1990s, initiatives such as the website Scorecard™ demonstrated the potential to improve communication on environmental issues with the public. This website, developed by Environmental Defense, offers data about chemicals ranging from health effects, hazard rankings, industrial and consumer uses, environmental releases and transfers, risk assessment, and regulations.[83] Users can enter any U.S. zip code to retrieve local data about emissions in their community.

User groups could develop a series of case studies that aim to answer questions such as: What formats would be useful to government officials, business managers, and community leaders? How might the data be presented in ways to create incentives for using safer and more efficient products? What regular indicators or graphics might the media provide that would help business and government leaders as well as individuals connect their actions to the effect on materials flowing into the economy and out into the environment?

Material flows accounts are also likely to benefit from the work of intermediaries. Writers, journalists, educators, local citizen groups, and businesses can work together to encourage imaginative use of MFA data for people of different interests and perspectives. One goal might be to encourage trade publications and the news media to report regularly on perhaps a half-dozen indicators displaying and comparing trends for selected material flows.

TASK 3: BUILD A PARTNERSHIP OF PROVIDERS AND USERS OF MATERIAL FLOWS DATA TO TAKE THE LEAD IN INSTITUTIONALIZING U.S. MATERIAL FLOWS ACCOUNTS

A dedicated group of experts has developed the methodology for material flows accounts and has raised its visibility in the research community over the past decade. Internationally, countries are cooperating to develop consistent methodologies and indicators through institutions such as the Organization for Economic Cooperation and Development. The U.S. data provider and user groups suggested here form the kernel of a constituency for institutionalizing material flows accounts in the United States. MFAs might, for example, be included as one responsibility of an Environmental Statistics Bureau. This process will likely require a congressional mandate.

These three steps would help realize the promise of material flows accounts to support continued U.S. prosperity while offering government and the public an effective tool for meeting the environmental challenge that comes from maintaining the continued flow of goods and services to society.

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Appendix A

MATERIALS COVERED IN THE WRI MATERIAL FLOWS DATA BASE

MINERALS

1. Abrasives (manufactured derivatives of Aluminum Oxide, Silicon Carbide)
2. Asbestos
3. Barite
4. Cesium
5. Clays
6. Kaolin
7. Ball
8. Fire
9. Bentonite
10. Fullers earth
11. Common
12. Diamond (Industrial)
13. Diatomite
14. Feldspar
15. Fluorspar
16. Garnet (Industrial)
17. Gemstones
18. Germanium
19. Graphite (Natural)
20. Gypsum
21. Helium
22. Iodine
23. Kyanite & Related Minerals
24. Magnesium Compounds
25. Mica (Natural), Scrap & Flake
26. Mica (Natural), Sheet
27. Nitrogen (Fixed), Ammonia
28. Peat
29. Perlite
30. Phosphate rock
31. Phosphoric acid
32. Potash
33. Pumice and Pumicite
34. Quartz Crystal (Industrial)
35. Salt
36. Caustic Soda
37. Chlorine
38. Sand & Gravel (Construction)
39. Sand & Gravel (Industrial)
40. Silicon
41. Soda Ash
42. Sodium Sulfate
43. Stone (Crushed)
44. Lime
45. Cement
46. Stone (Dimension)
47. Sulfur
48. Talc and Pyrophyllite
49. Vermiculite
50. Yttrium

METALS

51. Aluminum
52. Antimony
53. Arsenic
54. Beryllium
55. Bismuth
56. Boron
57. Bromine
58. Cadmium
59. Chromium
60. Cobalt
61. Columbium (Niobium)
62. Copper
63. Gallium
64. Gold
65. Indium
66. Iron ore
67. Iron and steel
68. Iron and steel slag
69. Lead
70. Lithium
71. Magnesium Metal
72. Manganese
73. Mercury
74. Molybdenum
75. Nickel
76. Platinum-Group Metals
77. Rare Earths
78. Rhenium
79. Rubidium
80. Scandium
81. Selenium
82. Silver
83. Strontium
84. Tantalum
85. Tellurium
86. Thallium
87. Thorium
88. Tin
89. Titanium
90. Tungsten
91. Vanadium
92. Zinc
93. Zirconium and Hafnium

AGRICULTURE

94. Wheat
95. Rye
96. Rice
97. Corn
98. Ethanol
99. Oats

100. Barley
101. Sorghum
102. Cottonseed
103. Soybeans
104. Flaxseed
105. Cotton
106. Sugar beets
107. Sugar Cane
108. Commercial Vegetables
109. Potatoes
110. Sweet Potatoes
111. Hay
112. Hops
113. Millet
114. Peanuts
115. Tobacco
116. Honey
117. Tree Nuts
118. Mushrooms
119. Beans, dry edible
120. Citrus Fruit
121. Non-citrus Fruit
122. Cattle
123. Beef
124. Hogs
125. Pork
126. Chickens
127. Chicken Meat
128. Turkeys
129. Turkey Meat
130. Sheep
131. Mutton and Lamb Meat
132. Wool
133. Milk and Dairy Products
134. Eggs
135. Animal Manure
136. Animal By-Products
137. Rubber
138. Fishery Products
139. Yard Trimmings

FORESTRY

138. Industrial Roundwood
139. Lumber
140. Plywood & Laminated Veneer Lumber (LVL)
141. Wood Panels
142. Pulpwood
143. Woodpulp
144. Paper & Board
145. Fuelwood
146. Other Industrial Roundwood

ENERGY

147. Natural Gas (Methane)
148. Pentanes Plus
149. Butane
150. Propane
151. Ethane
152. Crude Oil
153. Asphalt & Road Oil
154. Jet Fuel (inc. Aviation Gasoline)
155. Distillate Fuel Oil
156. Kerosene
157. Lubricant
158. Motor Gasoline
159. Petroleum Coke
160. Residual Fuel Oil
161. Coal
162. Coke
163. Combustion products

Appendix B

GLOSSARY OF TERMS

Bioaccumulative. Accumulation of a substance, such as a toxic chemical, in various tissues of a living organism: *the bioaccumulation of mercury in fish*.

Chemical Abstract Service (CAS) Number. Unique identification number for a chemical as designated by the Chemical Abstract Service, a division of the American Chemical Society. The classifications included approximately 22 million chemicals in 2003. CAS numbers are used in reference works, databases, and regulatory compliance documents by many organizations around the world to identify substances without the ambiguity of chemical nomenclature.

Commercial/Consumer Product Category. Categories for designating intended consumer uses for chemically formulated consumer products. The classification is used in reporting under the 2005-2006 amendments for the Toxic Substances Control Act Inventory Update Rule.

Comparative Risk Assessment. A qualitative process to rank or compare environmental problems or programs by risk (likelihood of injury or damage that is or can be caused by a substance, technology, or activity) to human health and to the environment. It is used by EPA. The results help evaluate and reset priorities for environmental protection.

Data Protocols. A standard procedure for regulating data organization, presentation, and transmission between computers.

Dead Zone in the Gulf of Mexico. An area roughly the size of the state of Connecticut located at the mouth of the Mississippi River that experiences a condition of low oxygen called "hypoxia" caused by the flow of excessive nutrients—including nitrogen and phosphorous—that trigger algal blooms, eventually depleting the supply of dissolved oxygen and causing fish, shrimp, crabs, and other sea life to die or migrate.

Environmental Impact Coefficients. Numerical coefficients relating environmental and human health effects to dosages or quantities of materials. The coefficient establishes a quantitative correlation between a material flow and its related impact.

Government Performance and Results Act of 1993 (GPRA). Holds federal agencies accountable for using resources wisely and achieving program results. GPRA requires agencies to develop plans for what they intend to accomplish, measure how well they are doing, make appropriate decisions based on the information they have gathered, and communicate information about their performance to Congress and to the public. *Also see Performance indicators.*

Green Chemistry. Branch of chemistry with the objective of promoting innovative chemical technologies that reduce or eliminate the use or generation of hazardous substances in the design, manufacture, and use of chemical products.

Industrial Function Category. Refers to categories for designating the intended industrial function for chemically formulated products and is used in reporting under the 2005 and 2006 amendments to the Toxic Substances Control Act Inventory Update Rule.

Life Cycle. Flow of material through successive phases of economic activity and into the natural environment. Phases can be defined in different ways. TSCA introduced this approach into public policy by covering manufacture, processing, distribution, use, and disposal.

Material Flows Data Sheet. A template developed by WRI to standardize data to be entered into material flows accounts.

Organic Wastewater Contaminants. Materials that enter waterways and are associated with human, industrial, and agricultural wastewater. They can include antibiotics, other prescription drugs, nonprescription drugs, steroids, reproductive hormones, personal care products, products of oil use and combustion, and other extensively used chemicals.

Performance Indicators. Measures the distance between a current situation and a desired situation or target, a distance-to-target assessment.

Persistent Toxic Material. Refers to a toxic compound that remains intact for an extended period after being introduced into the environment. It is slow to metabolize into benign constituents.

Physical Input-Output Tables (PIOT). Modeled on national economic input-output accounts. The tables describe the flows of material and energy within the economic system and between the economic system and the natural environment. The tables also show the physical accumulation of materials in the economy but not stocks of man-made or natural capital.

Pollution Prevention. Use of materials, processes, or practices that reduce or eliminate the creation of pollutants or wastes at the source. It includes practices that reduce the use of hazardous materials, energy, water, or other resources as well as practices that protect natural resources through conservation or more efficient use.

Pollution Prevention Act of 1990. Focuses industry, government, and public attention on reducing the amount of pollution through cost-effective changes in production, operation, and raw materials use. It identifies source reduction as fundamentally different and more desirable than waste management or pollution control.

Primary Feedstock. Materials used as basic ingredients in the manufacture of a commodity chain.

Product Registries. Contain information on chemical substances and products. National legislation in Nordic countries, such as Sweden, require manufacturers and importers to report annually on the amounts of chemical substances in their products that can cause human health effects such as allergies, cancer, or birth defects. Data in the registries are used to support risk assessments, statistical calculations, substance flow analyses, and supervision activities.

Synthetic Organic Chemicals (SOCs). Man-made substances containing mainly carbon, hydrogen, nitrogen, and oxygen.

Toxic Substances Control Act (TSCA). Enacted in 1976 by Congress to give EPA the ability to track industrial chemicals produced or imported into the United States. Under TSCA, EPA screens new chemicals and can require reporting or testing on existing chemicals that may pose an environmental or health hazard. The law provides power to ban or otherwise limit the import, manufacture, or use of those chemicals found to pose an unreasonable risk.

Toxics Release Inventory (TRI). A publicly available EPA database established under the Emergency Planning and Community Right-To-Know Act of 1986. Industrial and federal facilities report annually on the amounts of any of about 650 listed chemicals released to air, water, and soil and transferred to waste management facilities.

Volatile Organic Compounds (VOCs). Any organic compound that participates in atmospheric photochemical reactions in which they tend to volatilize or evaporate.

Waste Minimization Priority Chemicals. A list of 30 chemicals found in hazardous waste and documented as contaminants to air, land, water, plants, and animals. The Partnership for Environmental Priorities, formed in 2002, is expanding the list of priority chemicals and setting a new goal to eliminate the hazardous waste containing them.

Waste. An unusable or unwanted substance or material. Something such as steam, which escapes without being used, or a used refrigerator, a solid waste that must be disposed of. Waste is usually defined as solid rather than liquid or gas in environmental policy, although all are wastes in the economic sense. Liquid and gaseous wastes are usually referred to as pollutants or releases.

About World Resources Institute

World Resources Institute is an environmental research and policy organization that creates solutions to protect the planet and improve people's lives.

WRI's work is concentrated on achieving progress toward four key goals:

- Protect Earth's living systems
- Increase access to environmental information
- Create sustainable enterprise and opportunity
- Reverse global warming.

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