MEASURING MATERIAL FLOWS AND RESOURCE PRODUCTIVITY

Volume I.
The OECD Guide

OECD

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INTRODUCTION

This report is part of the **OECD programme on material flows and resource productivity** that supports the implementation of the **OECD Council recommendation** on MF and RP adopted in April 2004. It is the first volume of a **series of guidance documents on *Measuring material flows and resource productivity*** that have been drafted in a joint effort by a group of experts from OECD countries led by the OECD Secretariat[1]. It benefited from contributions by members of the OECD Working Group on Environmental Information and Outlooks and the Working Group on Waste Prevention and Recycling, the Eurostat Task Force on Material Flows, and the London Group on Environmental Accounting. In developing this report, the co-operation of environmental administrations, statistical services and material flow experts in countries has been invaluable. Our sincere thanks are therefore extended to all concerned.

The work has benefited from a **sequence of workshops** hosted by member countries (Helsinki, June 2004; Berlin, May 2005; Rome, May 2006; Tokyo, September 2007), that brought together environmental administrations, statistical services, material flow experts and researchers.

The guidance documents provide **guidance on methodological and measurement** issues related to material flow analysis (MFA), including the development of material flow accounts and related indicators. Emphasis is put on tools that can be used by country governments to support the development and implementation of **national policies** and related **international work**.

The main objectives are to:

- Provide an **accessible guide** to the measurement of material flows (MF) and resource productivity (RP) for those involved in constructing and interpreting such measures, including national statistical offices, relevant government agencies, policy analysts and researchers; and facilitate the dissemination and uptake of existing experience and guidance.
- Identify **desirable characteristics** of MF and RP measures in accordance with policy questions and uses, and by reference to a **coherent framework** that links the concepts of system analysis and integrated environmental economic accounting.
- Improve **international harmonisation and convergence**: although the documents are not prescriptive, they point out those areas in which harmonisation of methods is recommended so that results are coherent and can be used in international work. Some **diversity** in their implementation is expected, for example in the coverage of natural resources or materials that necessarily reflects the varying economic and environmental importance of a given resource or material flow for different countries.

The guidance documents reflect the **state of the art** concerning experience with material flow analysis and related indicators in member countries. It is expected that they will evolve as ongoing efforts on methodologies and measurement systems will show results and as more feedback will become available on the policy uses of MF information and indicators.

1 Experts and consultants: Mr. Derry Allen, Mr. Stefan Bringezu, Mr. Aldo Femia, Mr. Tomas Hak, Mr. Jan Kovanda, Mr. Yuichi Moriguchi, Mr. Heinz Schandl, Mr. Karl Schoer, Mr. Eric Turcotte, Ms Aya Yoshida. OECD Secretariat: Ms Myriam Linster. The financial and in-kind support of the Czech Republic, Finland, Germany, Italy, Japan, Luxembourg, and the United States is gratefully acknowledged.

The guidance documents include:

- ***Volume I. The OECD guide.***

  Volume I describes the full range of MF approaches and measurement tools, with a focus on the national level and emphasis on areas in which practicable indicators can be defined. It is targeted at a non expert audience. It includes (i) an overall framework for material flow analysis (MFA), (ii) a description of different kinds of measurement tools, (iii) a discussion of those issues and policy areas to which MFA and material flow indicators can best contribute, and (iv) guidance on how to interpret material flow indicators. It is illustrated with a selection of practical examples from countries' experience and is complemented with a glossary.

- ***Volume II. The accounting framework.***

  Volume II provides a theoretical and technical description of the concepts and methodologies of material flow accounting. It is targeted at an expert audience. It draws upon the Handbook on national accounting - Integrated Environmental and Economic Accounting (the SEEA handbook), developed jointly by the United Nations, the European Commission, the IMF, the OECD, and the World Bank and on the guide published by Eurostat in 2001 Economy-wide material flow accounts and derived indicators – A methodological guide. It has benefited from co-operation with Eurostat and with the London Group on Environmental Accounting, and consultations with the UNSD and its Committee of Experts on Integrated Environmental Economic Accounting.

- ***Volume III. Inventory of country activities***.

  Volume III takes stock of activities related to the measurement and analysis of natural resource and material flows in place or planned in OECD countries and in selected non member economies. It describes the main features that characterise such activities and the extent to which information on material resources is used in environmental reporting and in decision making. It is designed to provide a factual basis for the further exchange of experience and information, and for sharing lessons at international level.

- ***Volume IV. Implementing national MF Accounts*** (forthcoming, prepared jointly with Eurostat).

  Volume IV provides practical guidance to assist countries in implementing national material flow accounts. It is targeted at practitioners of material flow accounting. It is constructed in a modular way to reflect several levels of ambition and completeness of accounts, and is being developed stepwise. The first edition will focus on the establishment of simple economy-wide material accounts building on a set of core tables tested and used by Eurostat.

The guidance documents are complemented by a **synthesis report** that summarises the work carried out, takes stock of progress made, and adds selected examples from applications of MFA.

The guidance documents are published on the responsibility of the Secretary General of the OECD.

MEASURING MATERIAL FLOWS AND RESOURCE PRODUCTIVITY

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EXECUTIVE SUMMARY

Since 2004, OECD countries have been working together with the OECD Secretariat and other international partners to improve their knowledge about material flows and resource productivity and to develop common measurement systems and indicators. The objective is to enable sound, fact-based material flow analysis at national and international level, and to inform related policy debates.

This report presents results from this work. It builds on the expertise of the OECD Working Group on Environmental Information and Outlooks and a small group of experts. It has benefited from the active support of member **countries** and from a sequence of **workshops** hosted by member countries and organised in co-operation with the OECD Working Group on Waste Prevention and Recycling (WGWPR): Helsinki (June 2004), Berlin (May 2005), Rome (May 2006), Tokyo (September 2007).

The focus of this report is on the measurement of material flows (MF) and resource productivity (RP) in accordance with policy questions and uses. It provides an **accessible guide to material flow analysis and indicators** for those involved in constructing and interpreting such measures.

NATURAL RESOURCES, MATERIALS AND THE ECONOMY

Natural resources are fundamental for the economy and human welfare.

Natural resources are fundamental for the economy and human welfare. They provide raw materials, energy, food, water and land, as well as environmental and social services. Making sure that they are managed well and used efficiently is key to economic growth, environmental quality and sustainable development.

The way natural resources are used and managed has **economic, social and environmental consequences** that often extend beyond the borders of single countries or regions and that affect future generations. It has consequences on:

- The rate of exploitation and the productivity of **natural resource stocks**.
- The **environmental pressures** associated with the extraction, processing, use and disposal of materials.
- International **trade and market prices** of raw materials and other goods.
- The **productivity** and the competitiveness of the economy.

Using them efficiently is important for environmental quality, economic growth and prosperity.

In recent decades, worldwide use of many materials has been rising, amid growing **demands** from OECD countries and fast growing economies. International commodity **markets** have expanded, with increasing **international flows**, increasing **mobility** of production factors, and expanding **linkages** among countries and regions. Developments in market **prices** of many commodities and risks of disruptions in materials **supply** have become important issues for governments and businesses alike.

At the same time, many valuable materials contained in **waste** continue to be disposed of and are potentially lost for the economy. This has added to the long-standing concerns about the **sustainability** of natural resource use and the negative **environmental impacts** associated with their production and consumption and their end-of-life management.

Achieving **sustainable resource use** and ensuring that the flows of materials are managed in an **efficient way** through the economic system is thus critical, not only from an environmental perspective but also from an economic and trade perspective. It helps improve resource **productivity**, achieve efficiency gains and secure adequate **supplies** of material resources to the economy, while at the same time limiting the adverse **environmental impacts** associated with their extraction, processing, use and disposal.

Policies and actions

Many **countries** address these issues in their national sustainable development strategies or environmental plans. They have launched initiatives to promote waste prevention, integrated product policies, 3R (Reduce, Re-use, Recycle) related policies, sustainable materials management, and circular economy approaches.

Many **business sectors** address these issues by establishing stewardship programmes for materials and products, investing in R&D and using advanced technologies to increase materials and energy efficiency, enhancing environmental management, promoting eco-design and coherent materials supply and use systems.

At international level, these issues have been addressed by the Heads of State and Government of **G8 countries**, and are actively promoted by the **OECD**, the **European Commission** and **UNEP**. An **International Panel** on Sustainable Resource Management has been set up to address resource efficiency issues from a life-cycle perspective, and provide independent scientific assessment on the associated environmental impacts. Sustainable resource use is further supported by international efforts to promote good governance in the **raw materials sector** and to make the management of natural resource rents more transparent.

Information needs

Putting in place **policies** that promote sustainable resource use and improve resource productivity in the long term, requires a good **understanding** of the natural resource basis of the economy, supported with high quality **information** on material flows.

Almost every country measures its **economic activity**, and many countries monitor their labour and capital **productivity**, and their **energy efficiency**. But information is insufficient to give an integrated view of how minerals, metals, energy, timber or water flow through the economy, from the moment they are mined, felled or imported through processing, consumption and recycling to final disposal. And little is known about how this affects the productivity of the economy and the quality of the environment.

Filling knowledge gaps with Material Flow Analysis

Material Flow Analysis (MFA) is among the most useful tools to help fill these knowledge gaps and guide decision making.

The principles of MF studies and of statistical approaches towards material balances date back to the 1970s. In recent years, **good progress** has been made in developing methodologies for MFA, and the number of practical applications is growing. Countries are however at a variety of stages in developing and using MFA. Full development will take some years and each country will need to decide what is appropriate for its circumstances. This needs to be accompanied with further conceptual, methodological and analytical work and harmonised guidance to achieve **greater convergence** of individual initiatives and to facilitate wider dissemination and uptake of existing experience.

By providing guidance on how to measure material flows and resource productivity and how to develop related indicators, **this OECD guide is a first step** in this direction. It may evolve in future as ongoing efforts on methodologies and measurement systems will show results and as more feedback from policy uses will become available.

Prospects and future work

More work is needed in particular to:

- Monitor physical trade flows by origin and destination
- Monitor flows of secondary raw materials (recycled or reused) and of recyclable materials
- Develop methods to assess the environmental impacts of materials use
- Measure indirect flows (domestic and trade related) and develop common conversion factors and coefficients
- Provide industry-level and material-specific information to indicate opportunities for improved performance and efficiency gains.
- Identify a balanced set of indicators for use in international work and that countries can adapt to suit their own needs and circumstances.

WHAT IS MATERIAL FLOW ANALYSIS?

A family of tools

that use the principle of mass balancing

to study how flows of materials interact with the economy and the environment.

Material Flow Analysis (MFA) is the study of physical flows of natural resources and materials into, through and out of a given system (usually the economy). It is based on methodically organised accounts in physical units, and uses the principle of **mass balancing*** to analyse the relationships between material flows (including energy), human activities (including economic and trade developments) and environmental changes.

The principle of **mass balancing** is founded on the first law of thermodynamics (called the law of conservation of matter), which states that matter (mass, energy) is neither created nor destroyed by any physical process.

Material flows can be analysed at various **scales** and with different **instruments** depending on the issue of concern and on the objects of interest of the study. The analysis can be applied to the complete collection of all resources and products flowing through a system to single chemical elements. It can be applied to the global or the national economy, an industry, an enterprise, a city or a river basin.

The term MFA therefore designates a **family of tools** encompassing a variety of analytical approaches and measurement tools. These tools range in scope from economy-wide to substance or product-specific analysis, and input-output analysis. Each type of analysis is associated with **MF accounts** or other measurement tools, and can be used to derive various types of **indicators**. Often a combination of tools is necessary to gain the required insights. (Box 1).

MFA provides an integrated view of physical resource flows

MFA enhances the understanding of the **material basis of the economy** and the associated economic supply and demand issues and helps **identify inefficient use** of natural resources, energy and materials in process chains or the economy at large that would go undetected in conventional monitoring systems. It achieves this by using already available production, consumption and trade data in combination with environment statistics, and by improving modelling capacities.

The most complete applications take a **holistic approach** and encompass so-called **unused or indirect flows*** of materials that do not enter the economy as priced goods. The underlying rationale is that every movement or transfer of materials or energy from one place to another has repercussions on the environment and has the potential to alter the environmental balance.

Unused and indirect flows are of relevance from an environmental point of view because they can add to the pollution burden, disrupt habitats or alter landscapes, but do not enter the economy as priced goods (e.g. mining overburden; pollutants and waste generated upstream in a production process and that occur outside the system under review). Much of these flows are **hidden** and not seen in economic accounts or in trade and production statistics.

Although MFA is only one approach amongst others, it is the **only tool that can**:

- Provide an **integrated view** of physical resource flows through the economy.
- Capture **flows that do not enter the economy** as priced goods, but that are relevant from an environmental point of view.
- Reveal how flows of materials **shift among countries** and within countries, and how this affects the **economy and the environment** within and beyond national borders.

Which policy areas benefit most?

These characteristics make MFA a useful tool for examining **trade-offs** between policies and for understanding the implications of decisions that depend on **interrelationships** in the economy and the environment. It can be used to analyse issues that **cut across different media and policy areas** and support decisions that have economic, environmental and social implications. Potentially, a wide range of government agencies, ministries and departments will find use for these types of analysis. It is particularly useful in three broad **policy areas** (Table 1):

- economic, trade and technology development policies;
- natural resource management policies;
- environmental policies.

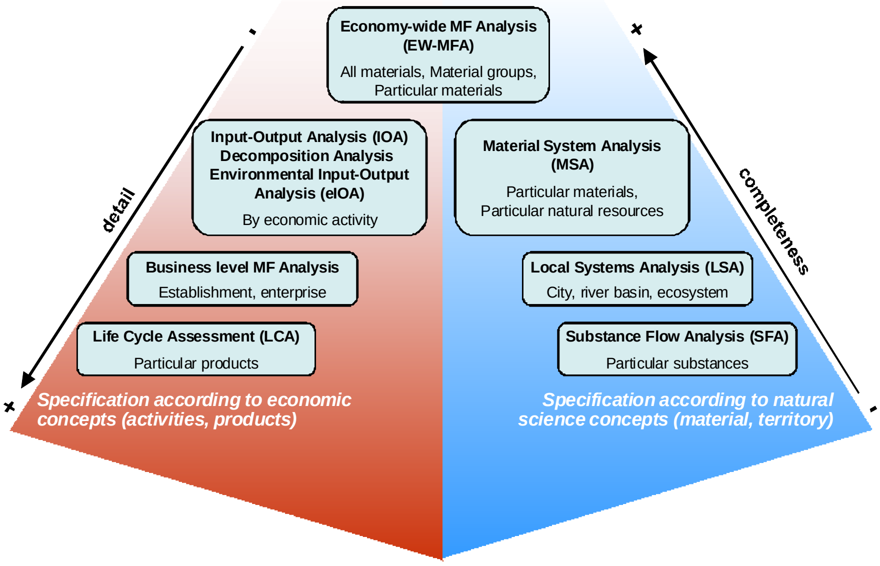
BOX 1. A multi-purpose family of tools

A material flow study can cover **any set of materials at various scales and levels of detail and completeness**.

Emphasis can be put on:

❶ **all materials entering and leaving the national economy;**
❷ **the industry level, enterprise level, and product level, from product groups down to specific products;**
❸ **certain materials and substances, from the national down to the local level;**
❹ **a combination of specifications.**

Overall architecture of MFA and related tools



Types of MF related analyses and associated issues of concern

Issue of concern	**Specific concerns related to environmental impacts, supply security, technology development**			**General environmental and economic concerns related to the throughput**		
	within certain businesses, economic activities, countries, regions			**of substances, materials, manufactured goods**		
	associated with			*at the level of*		
Object of interest	**Substances** chemical elements or compounds	**Materials** raw materials, semi-finished goods	**Products** (manufactured goods) batteries, cars, computers, textiles	**Businesses** establishments, enterprises	**Economic activities** mining, construction, chemical industry, iron& steel industry	**Countries, regions** total materials groups of materials, particular materials
Type of analysis	**Substance Flow Analysis**	**Material System Analysis**	**Life Cycle Assessment**	**Business level MF Analysis**	**Input-Output Analysis**	**Economy-wide MF Analysis**

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Substance flow analysis — Substance flow analysis and accounts (SFA) monitor flows of specific substances (e.g. Cd, Pb, Zn, Hg, N, P, CO_2, CFC) that are known for raising particular concerns as regards the environmental and health risks associated with their production and consumption.

Material system analysis — Material system analysis (MSA) is based on material specific flow accounts. It focuses on selected raw materials or semi-finished goods at various levels of detail and application (e.g. cement, paper, iron and steel, copper, plastics, timber, water) and considers life-cycle-wide inputs and outputs. It applies to materials that raise particular concerns as to the sustainability of their use, the security of their supply to the economy, and/or the environmental consequences of their production and consumption.

Life cycle assessments — Life cycle assessments (LCA) are based on life cycle inventories. They focus on materials connected to the production and use of specific products (e.g. batteries, cars, computers, textiles), and analyse the material requirements and potential environmental pressures along the full life cycle of the products. LCA can equally be applied to services, and are standardised in ISO 14010.

Business level MFA — Business level material flow analysis and accounts monitor material flows at various levels of detail for a company, a firm or a plant.

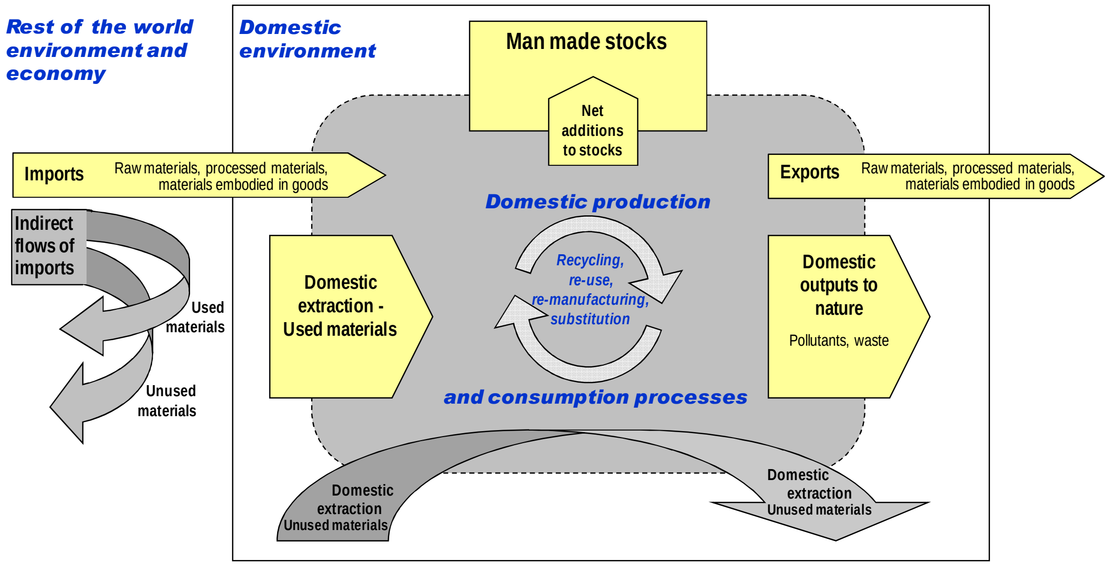
Input-Output analysis — Input-Output analysis (IOA) is based on physical input-output tables (PIOTs) that record material flows at various levels of detail to, from and through the economy, by economic activity and final demand category. It can also make use of NAMEA-type tables or of hybrid flow accounts.

Economy-wide material flow analysis — Economy-wide material flow analysis (EW-MFA) is based on national economy-wide material flow accounts (EW-MFAcc) that record all materials entering or leaving the boundary of the national economy. Data from these accounts can easily be aggregated for communication purposes and, if well structured, can be used for many other purposes (e.g. in-depth analysis; material specific indicators, modelling).

Source: OECD.

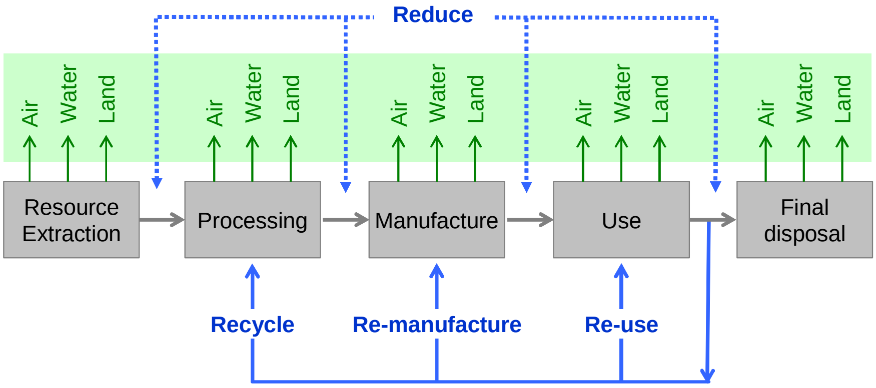
BOX 2. Material balance and flow schemes

Economy-wide material balance scheme



- Material resources used in an economy stem from raw materials extracted from natural resource stocks in the country (domestic material extraction) or extracted from natural resource stocks abroad and imported in the form of raw materials, semi-finished materials and materials embodied in manufactured goods.
- Material resources are extracted from the sub-soil and water bodies, or harvested from forests and farm land. The usable parts of these resources enter the economy as material inputs where they become priced goods that are traded, processed and used. Other parts remain unused in the environment. These materials are called "unused materials" or "unused extraction". Examples include mining overburden, soil and rock excavated during construction and not used elsewhere, dredged sediments from harbours, harvest residues.
- Some materials accumulate in the economy where they are stored in the form of buildings, transport infrastructure or durable and semi-durable goods, such as cars, industrial machinery or household appliances. These materials are sooner or later released back to the environment in the form of demolition waste, end-of-life vehicles, e-waste, bulky household waste, etc.
- After use in production and consumption activities, the materials leave the economy as an output either to the environment in the form of residuals (pollution, waste), or to the rest of the world as exports in the form of raw materials, semi-finished materials and materials embodied in manufactured goods.
- When materials are imported for use in an economy, their upstream production is associated with unused materials that remain abroad, and with the generation of residuals (pollution, waste). These "indirect flows" of materials take into account the life-cycle dimension of the production chain, but are not physically imported. Their environmental consequences occur in countries from which the imports originate.

Flows of materials through the commercial life-cycle



Source: OECD.

Table 1. Policy applications of MFA

Policy areas		Relevant MFA functions	Appropriate MFA tools
Economic, trade and technology development policies	Economic policies	♦ Measure aspects of the physical performance of the economy. ♦ Analyse the materials requirements for activities that involve construction, reconstruction, maintenance and disposal of infrastructure. ♦ Measure the degree of "decoupling" between direct and indirect environmental pressures (pollution, waste, primary resource inputs) and economic growth	♦ Economy-wide MFA ♦ Physical I-O analysis *In conjunction with*: ♦ Productivity measures ♦ Economic modelling ♦ Analysis of energy requirements
Economic, trade and technology development policies	Trade aspects & supply patterns	♦ Support structural analysis of the global economy in physical terms: effects of globalisation on international material flows; substitution of domestic raw materials with imported ones; interaction with production & consumption patterns. ♦ Monitor the structural effects of trade and environment measures on international materials markets and on flows of environmentally significant materials (e.g. hazardous materials; secondary raw materials, recyclable materials). ♦ Monitor the environmental implications of changes in international material flows, including (i) environmental pressures from indirect flows abroad associated with trade; (ii) environmentally significant materials embedded in imported goods; (iii) environmental risks related to international transport of materials, etc.	♦ Economy-wide MFA covering trade flows by origin/destination; ♦ Physical I-O analysis; ♦ Environmental I-O analysis; *In conjunction with:* ♦ Monetary I-O tables; ♦ International trade statistics; ♦ International transport statistics.
Economic, trade and technology development policies	Technology development	♦ Guide the development of new technologies and identify those that would severely strain material availability or generate excessive additional environmental pressures. ♦ Identify potential areas for research on substitutions of materials and on the availability of materials for the development of new technologies. ♦ Detect opportunities for new technologies that help reduce inefficiencies in energy and materials use, increase domestic reuse or recycling and the use of alternative materials.	♦ Material system analysis and material specific accounts; ♦ Life cycle analysis of products *In conjunction with:* ♦ Value chain analysis
Natural resource management policies		♦ Assess the status and trends of a country's natural resources. Monitor sustainable production levels (e.g. forest resources) and support related management plans. ♦ Examine the demand, scarcity and raw material requirements, based on the full material cycle and understand what is behind price and production trends in commodities over extended periods of time. ♦ Assess mineral systems by tracking (i) raw materials used in the economy, (ii) the flow of a specific material in the economy as a commodity (iii) the flow of different materials as a product, (iv) material stocks in use, reuse and disposal in a country. ♦ Assess energy systems by tracking energy carriers used in the economy, by giving insights into multiple uses, including non-fuel uses (e.g. plastics, synthetic fibres).	♦ Material system analysis and resource specific accounts; *In conjunction with:* ♦ Natural resource accounts ♦ Information on proven reserves and rates of discovery. ♦ Energy accounts and statistics ♦ Modelling
Environmental policies	Integrated pollution prevention & control	♦ Map the flows of nutrients or contaminants in a region, country or river basin and identify whether, where and to what extent these flows contribute to environmental degradation "downstream". ♦ Estimate environmental pressures from metal extraction and production, the part due to inefficiencies in production technologies and the benefits that could be gained from new technologies and from improved recovery and recycling. ♦ Monitor and help understand indirect and unused materials flows and their effects on the environment, at home and abroad.	♦ Economy-wide MFA with detailed breakdown of materials. ♦ Substance flow analysis. ♦ Material system analysis and material specific accounts. *In conjunction with:* ♦ Waste statistics & accounts
Environmental policies	Integrated waste and materials management	♦ Analyse trends in waste generation, and how they affect opportunities for (i) resource conservation, (ii) resource productivity, and (iii) material recovery and recycling. ♦ Assess the economic benefits and costs to keeping materials in the active materials stream and to minimising the amounts going to final disposal. ♦ Assess developments in markets for reused and recyclable materials. ♦ Identify areas for research on (i) energy conservation and recovery, (ii) materials recycling, (iii) alternative materials and (iv) new technologies.	♦ Various MFA tools distinguishing between primary and secondary raw materials, and recyclable materials. *In conjunction with:* ♦ Waste statistics & accounts ♦ Cost benefit analysis ♦ Modelling
Environmental policies	Product related policies	♦ Examine source reduction, substitution, and recyclability of the materials composing a product and help understand the synergistic nature of the flows of these materials. ♦ Examine environmental impacts of products, in particular products with toxic ingredients (e.g. lead paint, asphalt roofing, batteries with cadmium). ♦ Explore design issues that affect the environment at end of product life, and identifying leverage points for green design and pollution prevention, and implications of a policy shift (e.g. ban on use of certain materials in particular products).	♦ Life cycle analysis & assessments
Environmental policies	Other	♦ Analyse the effects of environmental policy instruments on material flows and on the material supply mix. ♦ Analyse the benefits of government purchasing policies (e.g. for the availability of recycled or redesigned products to the market), and how they affect material flows ♦ Monitor environmental performance targets with industry and government.	♦ Various MFA tools *In conjunction with:* ♦ Cost benefit analysis ♦ Modelling ♦ EMS

ESTABLISHING THE INFORMATION BASIS: MATERIAL FLOW ACCOUNTS

What they are

The analysis of material flows usually builds on methodically organised accounts in physical units. These **Material flow accounts** (MFAcc) use already available production, consumption and trade data in combination with environment statistics (on waste, emissions, etc.), and improved modelling. They provide a **coherent, multi-purpose database** at the bottom of the information pyramid. They form a basis for many types of analysis and enable the calculation of various types of indicators

MFAcc are physical flow accounts as described in the System of integrated Environmental Economic Accounting (SEEA). Unlike other physical flow accounts, MFAcc track both direct flows (i.e. flows physically entering the economy) and indirect and unused flows (i.e. flows not entering the economy, but associated to resource exploitation and to the up-stream production process of a product, and of relevance from an environmental point of view).

The **accounting concepts** involved are founded on the mass balance principle. This leads to the following accounting identity:

> **Material flow accounts** (MFAcc) are methodically organised accounts in physical units (usually tonnes) that quantify the flows of different types of materials (metals and other minerals, forest products, fossil fuel carriers, etc.) into, out of and possibly within a given system at different levels of detail and completeness.
>
> They record material flows from extraction and harvesting through product manufacture, product use, reuse/recycling and disposal, including discharges to the environment that are associated with each stage of these flows.

natural resource extraction + imports = residual output + exports + net addition to man-made stocks

i.e. the sum of material inputs into a system equals the sum of its material outputs, thereby comprising the materials accumulated as changes in stocks.

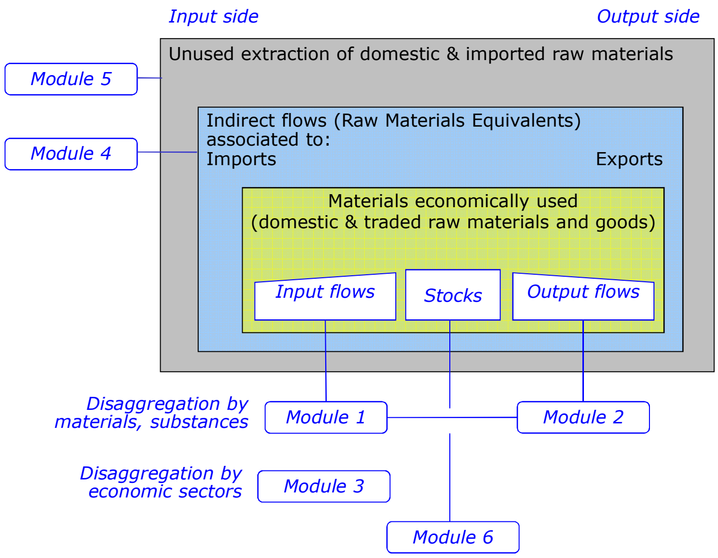
How to implement them

Before undertaking a national effort to establish MFAcc, it is important to carefully consider:

- the purposes and uses for which the accounts are to be established
- the institutional arrangements and partnerships required to ensure continuity of effort
- the costs and benefits of creating and maintaining the accounts
- the statistical basis available for populating the accounts.

A **step-wise approach** may be the most practical tactic to establishing the information base required for MFA. The **OECD** has developed a menu of options to help establish national MF accounts in practice. The menu comprises a **set of modules** to reflect several levels of ambition and completeness of accounts, and is so designed that it can be implemented equally well in part as in whole. Practical guidance is being developed jointly with **Eurostat**.

Hierarchy and sequence of steps for a system of national MF accounts



Each of these modules provides a basis for deriving material flow indicators.

MEASURING PROGRESS: MATERIAL FLOW INDICATORS

What they are

Material flow (MF) indicators help measure progress with resource productivity and materials use, and provide insight into the economic efficiency and environmental effectiveness of materials use in the production and consumption chain, up to final disposal.

> **Material flow indicators** are quantitative measures, which point to, inform about, describe, the characteristics of material flows and material resource use and which have a meaning or a significance that goes beyond that directly associated with the underlying statistics.
> Their role is to inform about key properties of the system being studied by making use of selected data, i.e. those that are most relevant for a given use or policy field.

MF indicators can be **derived from any MFA tool**, as well as from other statistics. They can cover any set of materials at various levels of details. In this guide, emphasis is put on indicators that can be used to support the development and implementation of **national policies and related international work**.

Functions and audiences

MF indicators serve **many purposes** depending on the level at which they are applied, and the specification of the material flows to be studied. They help communicate, guide decision making and promote policy integration and coherence.

A key function is to communicate the results of MFA in a way **adapted to users' needs**. Often, some degree of simplification is necessary, involving a trade-off between an indicator's relevance for users and policies and its statistical quality, analytical soundness and scientific coherence. Indicators should thus be regarded as reflecting the "best knowledge available" and need to be embedded in larger information systems (databases, accounts, monitoring systems).

MF indicators are particularly useful for **non-expert audiences**: the general public, journalists, managers and decision makers in the business and government sectors, policy-makers, including parliamentarians, and stakeholders from NGOs. They should therefore convey messages in a meaningful way that reduces the complexity and level of detail of the original data and **address concrete questions**. Examples of questions include:

Answering questions with the help of MF indicators

> ❶ What are the material requirements of an activity or an economy?
> ❷ How dependent is an activity or an economy on external material inputs or external material markets?
> ❸ How efficiently are material resources being used?
> ❹ What is the potential for improving resource productivity?
> ❺ What are the main environmental risks and pressures associated with natural resource and materials use?
> ❻ What are the main environmental consequences of international material flows?

The answers to these questions help monitor:

- The level and characteristics of physical resource use by an economy or activity.
- The environmental aspects of material resource use at national and international level.
- The effects of environmental and economic policies on materials use, and the implications of trade and globalisation for national and international material flows.

Main groups of indicators

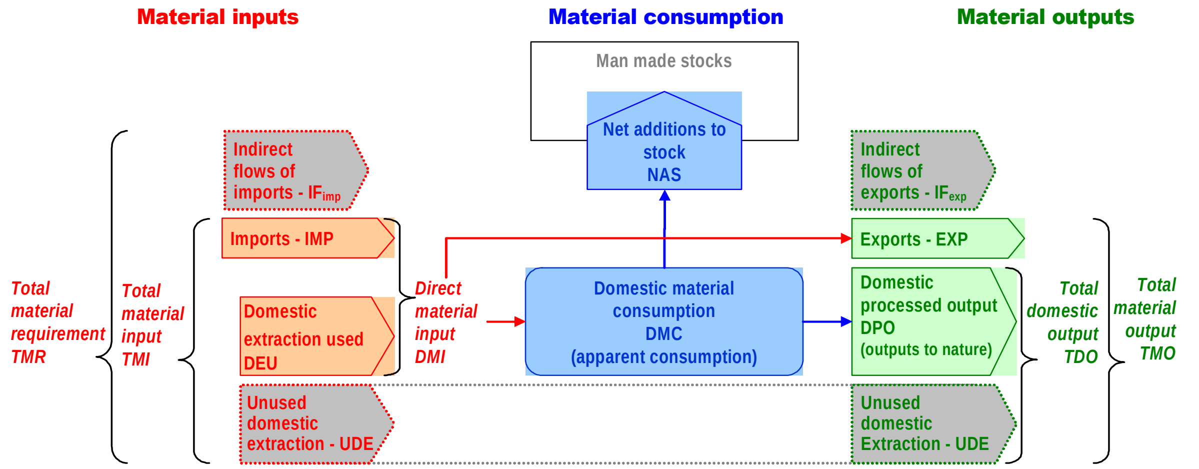
The most common indicators in use are derived from **economy-wide MFA** and from **physical input output analysis**. In accordance with the materials balance scheme, one distinguishes the following **main groups**: input indicators, consumption and balance indicators, and output indicators (Box 3). These indicators can be combined with each other or presented in conjunction with other indicators to give a **balanced picture** of the issue described. It is also possible to define **resource productivity indicators** that can be used in parallel with those describing capital or labour productivity.

How to use them

The appropriate use and interpretation of MF indicators in policy analysis is subject to the same **caveats** normally applied to other types of indicators (e.g. the need to always consider context). Most indicators need **qualification**, due to methodological and empirical shortcomings, and careful interpretation, due to differences among economies related to factors such as resource endowment, geography, demography and technology. Among other factors that play a role, are the **level of aggregation** of the indicators, and the way they can be related to environmental issues, to economic demand and supply issues, and to globalisation and trade issues.

One should therefore not forget the efforts that need to be made to **inform the users**, the public and the press about the value, objectives and limits of the indicators. This turns out to be a key element to ensure proper use and interpretation of MFA results.

BOX 3. Main groups of MF indicators and their relation to the materials balance



Input indicators Input indicators describe the materials mobilised or used for sustaining economic activities, including the production of export goods and services. They are closely related to the mode of production of a particular country or region. They are sensitive to changes in the level and patterns of foreign trade and to other factors such as a country's endowment in natural resources, and its level of technology development and uptake.

They show the **materials supply** to the economy, whether **extracted** from the domestic environment or **imported** (Domestic extraction used: DEU , Direct Material Input: DMI). They can also show the **total material requirements** of an economy, by recording not only materials supply, but also the **unused flows** that are associated with the extraction of materials and the indirect flows that are associated to imports but that take place in other countries (pollution, waste, unused extraction) (Total Material Requirement: TMR).

Consumption indicators Consumption indicators describe the **materials consumed by economic activities**. They are closely related to the modes of consumption. (Domestic Material Consumption: DMC), Total Material Consumption: TMC). The difference between consumption and input indicators is an indication of the degree of integration of an economy with the global economy, which also depends on the size of the economy.

Balance indicators Balance indicators describe the **physical growth of the economy**. They show net flows of materials added to the economy's **stock** taking into account gross flows added (in buildings, infrastructures and durable goods) and removed from the stocks (construction and demolition wastes, end-of life products). They can also show the physical **trade** surplus or deficit of an economy by taking into account materials coming from international trade. (Net Additions to Stock: NAS, Physical Trade Balance: PTB)

Output indicators Output indicators describe the material outflows related to production and consumption activities of a given country. They account for those materials that have been used in the economy and are subsequently leaving it. They show either the pollutant **emissions and waste**, or **exports**. They can also show the potential **environmental burden** of materials use, by recording in addition to emissions and waste, the unused flows of materials (Domestic Processed Output: DPO, Total Domestic Output: TDO)

Source: OECD.

Using reference values Adding reference values, such as benchmarks, thresholds, baselines, objectives or targets, will help users better **understand the significance** of the indicator values, and enables comparisons between data that are otherwise not easy to compare.

Using synergies with other indicators Integrating MF indicators in existing sets of environmental or sustainable development indicators, and using **balanced sets** of different MF indicators helps give a more representative picture of a situation and avoid misuse. In general, a balance needs to be struck between the wish to have as few indicators as possible and the need to keep each as intelligible, robust and transparent as possible.

Revealing the constituents The availability of detailed data on the composition and constituents of the indicators is an advantage for all indicators that focus on aggregate materials or material groups. It helps reflect the **materials mix** and changes in the mix over time, as well as the underlying structural changes in the economy.

Chapter 1.
NATURAL RESOURCES, MATERIALS AND THE ECONOMY

Natural resources and materials

are fundamental for the economy and human welfare. Their efficient management and use are key to economic growth and to the quality of the environment.

- **Sustainable resource use and resource productivity**
- **Knowledge gaps and information needs**
- **The value of material flow studies**

NATURAL RESOURCES, MATERIALS AND THE ECONOMY[2]

1. BACKGROUND AND POLICY CONTEXT

Natural resources are a major foundation of economic activity and human welfare. Their stocks are part of the natural capital and they provide raw materials, energy carriers, water, air and land, and support the provision of environmental and social services that are necessary to develop man-made, human and social capital. Natural resources differ in their physical characteristics, abundance and value to different countries or regions. Their efficient management and use are key to economic growth and sustainable development and are part of the many cross-sectoral issues with which governments are confronted. (Box 1).

The use of materials from natural resources in human activities and the related production and consumption processes have many environmental, economic and social consequences that often extend beyond the borders of individual countries or regions. This has a bearing on decisions cutting across many policy areas, ranging from economy, trade and technology development, to natural resource and environmental management, and to human health (Chapter 2).

Environmental consequences

From an environmental point of view, the use of natural resources and materials has consequences that occur at different stages of the resource cycle and that affect the quantity and quality of natural resource stocks and the quality of ecosystems and environmental media. It has consequences on:

- the rate of extraction and depletion of renewable and non-renewable resources.
- the extent of harvest and the reproduction capacity and natural productivity of renewable resources.
- the associated environmental burden (e.g. pollution, waste, habitat disruption) and its effects on environmental quality (e.g. air, climate, water, soil, biodiversity, landscape) and on related environmental services.

The type and intensity of these consequences depend on the kind and amounts of natural resources and materials used, the way these resources are used and managed, and the type and location of the natural environment from where they originate.

Social consequences

From a social point of view, the use of natural resources and materials has consequences on employment and on human health, and has implications for leisure habits connected to the presence and accessibility of particular resources, landscapes and ecosystems. It has also cultural implications when natural resources are a basic element of the cultural heritage of people. The way revenues and other financial flows related to resource production and supply are managed (in resource rich countries) has a bearing on income levels.

Economic consequences

From an economic point of view, the way natural resources are used and managed has consequences (i) on short term costs and long term economic sustainability, (ii) on the supply of strategically important materials, (iii) on the costs associated with the downstream management of materials, and

2 This chapter largely builds on "*Sustainable Development – Critical Issues*", Chapter 10. Natural Resource Management, OECD, 2001, and on earlier OECD work on natural resource management.

(iv) on the productivity of economic activities and industrial sectors. A development pattern that depletes natural resources without providing secure, long-term substitutes for the goods and services that they provide is unlikely to be sustainable.

Box 1. Characteristics and values of natural capital and natural resources

Natural capital comprises **natural resource stocks** (i.e. mineral and energy resources, soil resources, water resources, biological resources), **land and ecosystems**. All these resources are considered essential to the long-term sustainability of development for their provision of "functions" to the economy, as well as to mankind outside the economy and other living beings.

Natural resources are characterised by **three features** that distinguish them from other types of capital:

- Natural resources are not produced.
- If depleted or degraded their natural stocks cannot easily be replaced or restored.
- They form an integral part of larger ecosystems, and their depletion and degradation can lead to environmental degradation and reduced ecosystem services.

Natural resources are commonly divided into **non-renewable and renewable** resources:

- **Non-renewable** natural resources are exhaustible natural resources whose natural stocks cannot be regenerated after exploitation or that can only be regenerated or replenished by natural cycles that are relatively slow at human scale. Examples include metals and other minerals such as industrial and construction minerals, and fossil energy carriers, such as oil.
- **Renewable** natural resources are natural resources that, after exploitation, can return to their previous natural stock levels by natural processes of growth or replenishment. Conditionally renewable resources are those whose exploitation eventually reaches a level beyond which regeneration will become impossible at human scale (e.g. clear-cutting of tropical forests). Examples include timber from forest resources, freshwater resources, land resources, wildlife resources such as fish, agricultural resources.

Natural resources, land and ecosystems fulfil **three basic functions**:

- **Resource functions** when they are used as inputs in the economy and converted into economic goods and services. Examples are mineral deposits, timber from natural forests, and deep sea fish.
- **Sink functions** when they absorb pollution and waste generated by production and consumption processes.
- **Service functions** when they provide habitats for man and wild life. Service functions include ecosystem services and amenity functions (recreational and leisure services, landscape services), as well as survival functions such as the provision of clean air or clean water or protection against UV rays.

The **value of natural resources** depends both on:

- The **commercial return** from their use as inputs into the production of economic goods and services. These **use values** are generally captured in commercial markets. Most non-renewable resources (fossil fuels, minerals, metallic ores) and certain renewable resources (e.g. timber, agricultural products), once extracted or harvested, become priced goods with market values.
- Environmental, recreational and **other services** they provide. These **non-use values** are generally not captured in markets or are not valued for the full service provided, and their determination is complex.

Source: OECD, based on OECD (2001) *Sustainable development – Critical issues,* Chapter 10. Natural Resource Management, OECD, Paris; and on United Nations et al. (2003), *Integrated Environmental and Economic Accounting 2003-Handbook on national accounting*, New York.

Economic growth is generally accompanied by growing demand for raw materials, energy and other natural resources with consequences on market prices and on trade flows of these resources. Throughout the past decades, worldwide use of virtually every significant material has been rising, and concerns about shortages of stocks of natural resources and the security of supply of energy and other materials have been recurrent. Growing economic and trade integration has shifted many policy issues from local and national levels to global levels. It has enlarged the size of markets, allowed greater specialisation and mobility in production, increased the role of multi-national enterprises and led to an overall increase in international flows in raw materials and manufactured goods (OECD, 2007).

In recent years, prices for energy and other material resources have risen significantly amid growing demands from OECD and other countries, in particular fast growing economies such as China and India. These developments have implications for the ways in which natural resources are supplied to and used in the economy. They also have a bearing on decisions concerning mineral exploration, technology development and innovation. Hence, natural resource consumption and the economic efficiency of materials use have become important issues, adding to long standing concerns about the availability of resources and the environmental effectiveness of their use.

It is expected that in the next 50 years, world population will continue to grow, as will the world economy, placing increasing strains on a variety of material and energy resources and the global environment. This creates formidable economic and environmental challenges for policy- and decision-makers. It raises the question as to how to sustain economic growth and welfare in the longer term while keeping negative environmental impacts under control and preserving natural resources. Among the key issues relating to the use of non-renewable resources is whether the rate of discovery of new resources will continue to match the rate of use these resources and to what extent innovation will help developing alternative substitute materials. Experience indicates that in the longer term sustainable resource use and technological progress help de-coupling economic growth, increases in resource consumption and environmental degradation.

2. SUSTAINABLE RESOURCE USE AND RESOURCE PRODUCTIVITY

Against this background, achieving sustainable resource use and ensuring that the flows of materials are managed in an effective and sound way through the economic system is critical, not only from an environmental perspective but also from an economic and trade perspective.

The concept of sustainable resource use builds on an integrated and long-term approach to resource management. It encompasses aspects linked to the economic efficiency and environmental effectiveness of resource use at the various stages of the production and consumption chain, as well as related social aspects. In other words, it aims at optimising the net benefits from resource use within the context of economic development, by:

- Ensuring adequate supplies of renewable and non-renewable resources to support economic activities and economic growth.
- Managing the environmental impacts associated with the extraction, processing, use and end-of-life disposal of materials, to minimise adverse effects on environmental quality and human health.
- Preventing natural resource degradation and depletion.
- Maintaining non-commercial environmental services.

Sustainable resource use is also likely to contribute to increased resource productivity, i.e. greater output or value added per unit input of resources. Resource productivity has an impact on the production process and on economic growth through impacts on capital stocks, and through impacts on costs, especially in resource-intensive industries. These impacts can have positive economic effects as long as the costs of improved resource productivity do not exceed the cost reduction (Pearce, 2001). At the same time, improved resource productivity is in turn likely to be crucial in easing environmental constraints and in delivering greater welfare, as long as efficiency gains outweigh increases in demand. This is all the more important where natural resources and materials play a strategic role in the economic structure of a country.

Improving the resource productivity of the economy and implementing integrated approaches to natural resource use and materials management, are of increasing importance to many governments and businesses, as are instruments aimed at stimulating technological change that raises resource use efficiency.

Many countries have included the issue of efficient management and sustainable use of natural resources in their national sustainable development strategies or environmental plans, and have launched initiatives to promote waste prevention, sustainable materials management, 3R (reduce, reuse, recycle) related policies and circular economy approaches, and integrated product policies. Some countries work in partnership with industry to move towards sustainable use of natural resources and materials.

Many business sectors address these issues by establishing stewardship programmes for materials and products, investing in R&D and using advanced technologies to increase materials and energy efficiency, enhancing environmental management, promoting eco-design and coherent materials supply and use systems

Resource use and environmental sustainability

The OECD has defined four criteria for "environmental sustainability" that are in many respects relevant to material flows and resource productivity.

Regeneration: Renewable resources shall be used efficiently and their use shall not be permitted to exceed their long-term rates of natural regeneration.

Substitutability: Non-renewable resources shall be used efficiently and their use limited to levels which can be offset by substitution by renewable resources or other forms of capital.

Assimilation: Releases of hazardous or polluting substances to the environment shall not exceed its assimilative capacity; …

Avoiding Irreversibility: Irreversible adverse effects of human activities on ecosystems and on biogeochemical and hydrological cycles shall be avoided. The natural processes capable of maintaining or restoring the integrity of ecosystems should be safeguarded ….

Source: OECD (2001), OECD Environmental Strategy for the first decade of the Twenty First Century.

Sustainable resource use and resource productivity are also high on the international policy agenda. They are closely linked to Agenda 21 and to the plan of implementation of the 2002 Johannesburg World Summit on Sustainable Development. It has been addressed by the Heads of State and Government of G8 countries, and is actively promoted by the OECD, the European Commission and UNEP (Box 2).

- The Heads of State and Government of G8 countries paid specific attention to the various aspects of resource productivity at their summits in 2003, 2004, 2006, and 2007.
- The European Union has developed strategies on the sustainable use of natural resources, waste prevention and recycling, and integrated product policies.
- Governments of OECD countries adopted in 2004 a Recommendation on material flows and resource productivity in which they agreed to improve information and knowledge on material flows and resource productivity.
- UNEP is promoting sustainable consumption and production in response to the Plan of implementation of the 2002 World Summit on Sustainable Development. An International Panel on Sustainable Resource Management has been set up to tackle resource efficiency issues from a life-cycle perspective, and to provide independent scientific assessment on the associated environmental impacts.
- Sustainable resource use is further supported by international efforts to promote good governance in the raw materials sector (extraction and processing) and to foster transparency in the management of natural resource rents.

Box 2. International references to material flows and resource productivity issues

G8 summit references

In 2003, the Heads of State and Government of G8 countries, at their summit in France adopted an Action Plan on "Science and Technology for Sustainable Development" stating that G8 members "*will enhance their understanding of resource material flows and continue work on resources productivity indices, notably in the OECD*". (Evian, 1-3 June 2003)

This followed on the communiqué by G8 Environment Ministers who recognised "that it is essential to improve resource productivity" and noted with interest "Japan's proposal to launch an international joint research project on economy-wide material flow accounts to develop a common measurement system of material flow, building on existing work at the international level", and "that a common approach has to be elaborated in order to identify and develop indicators and indices to monitor the shift in consumption and production patterns". They invited "*the OECD to play a supportive role in that respect*". (Communiqué adopted by G8 Environment Ministers, Paris, 25-27 April 2003).

In 2004, the Heads of State and Government of G8 countries at their summit in the United States endorsed the "Reduce, Reuse and Recycle" (3Rs) initiative proposed by Japan as part of the follow-up to the Action Plan on "Science and Technology for Sustainable Development" adopted in 2003. (Sea Island, 9-10 June 2004).

In 2006, the Heads of State and Government of G8 countries at their summit in Russia adopted a Plan of Action on Global Energy Security emphasising the importance of energy efficiency and stating that "*As part of an integrated approach to the entire resource cycle we reaffirm our commitment to comprehensive measures to optimize the resource cycle within the 3Rs Initiative (Reduce, Reuse, Recycle). In furthering these efforts, we will set targets as appropriate taking account of resource productivity*." (St Petersburg, 15-17 July 2006).

In 2007, the Heads of State and Government of G8 countries at their summit in Germany agreed to increase transparency and good governance in the raw materials sector as a contribution to sustainable growth, and stated that "*based on sound life cycle analyses, we will … encourage conservation, recycling and substitution of raw materials, including rare metals, for sustainable growth*." (Heiligendamm, 6-8 June 2007).

OECD references

The Council of the OECD has adopted several policy and legal texts of relevance to sustainable resource use and resource productivity and concerning actions that Member countries agreed to carry out in the framework of the Organisation.

In 2001, OECD Environment Ministers and the OECD Council at ministerial level adopted the OECD Environmental Strategy for the First decade of the 21st Century that includes two objectives related to the efficiency of resource management:

- maintaining the integrity of ecosystems through the efficient management of natural resources with a focus on renewable resources such as freshwater and biodiversity.
- decoupling environmental pressure from economic growth and making integrated efforts to address consumption and production patterns, including by encouraging more efficient resource use and hence increases in resource productivity.

This follows on the recommendations formulated in 1997 of the High Level Advisory Group on the Environment to the Secretary General of the OECD: "*… it is now time for the OECD to concentrate on increasing resource productivity with the same effectiveness it applied to labour productivity. This should be done not just for environmental reasons, but also for economic and social reasons*" (OECD, 1997)

In 2004, the Council of the OECD adopted a Recommendation on material flows and resource productivity asking OECD countries to improve information and knowledge on material flows and resource productivity and to develop common methodologies and measurement systems, with emphasis on areas in which comparable and practicable indicators can be defined.

European Union references

The European Union, as part of its 6th Environmental Action Programme (6 EAP), has developed a thematic strategy on the sustainable use of natural resources for "*ensuring that the consumption of resources and their associated impacts do not exceed the carrying capacity of the environment, and breaking the linkages between economic growth and resource use".* It is complemented with a strategy on the prevention and recycling of waste and with integrated product policies (IPP) aiming at improving the environmental performance of products through their entire life-cycle. Other EU texts of relevance include an Environmental Technology Action plan.

UN references

The plan of implementation of the 2002 Johannesburg World Summit on Sustainable Development aims at changing unsustainable patterns of consumption and production. Governments, relevant international organizations, the private sector and all major groups should "*Encourage and promote the development of a 10-year framework of programmes in support of regional and national initiatives to accelerate the shift towards sustainable consumption and production to promote social and economic development within the carrying capacity of ecosystems by addressing and, where appropriate, delinking economic growth and environmental degradation through improving efficiency and sustainability in the use of resources and production processes and reducing resource degradation, pollution and waste*."

In 2007, UNEP established an International Panel on Sustainable Resource Management to provide independent scientific assessment on environmental impacts due to the use of resources over the full life cycle.

3. KNOWLEDGE GAPS AND INFORMATION NEEDS

Putting in place effective and integrated natural resource and materials management policies within the context of economic development is not easy. It is complicated by a number of factors including inter-temporal trade-offs, spatial and distributive aspects, interactions between different resources, as well as uncertainties about future demand and supply, and about the environmental impacts of their exploitation, processing, use, and disposal. It requires a good knowledge of:

- the use and depletion of resources;
- the stocks and flows of resources;
- technologies, recycling and substitution;
- physical properties, values and demands for environmental services provided by natural resources, and links between resource exploitation and use, and these services.

While the magnitude and flows of capital and human resources are tracked in great detail in economic accounts, and in social and labour statistics, natural resources are not yet tracked in a manner that enables a systematic evaluation of the ways in which they are used and how this impacts on the productivity of the economy and the quality of the environment. As a result, little is known about the links between natural resource exploitation and ecosystems, the values of non-commercial outputs, and the long-term environmental, economic and social implications of natural resource degradation and materials use.

Information on natural resources and their use is available from various statistical sources, including government sources, business reports and non-governmental groups. It is available on most commercial resources and their values. Information also exists on physical stocks and flows of particular resources (e.g. energy resources, forest resources, freshwater resources, certain mineral resources) and on certain parts of the process chains or the life cycle of selected materials and products. Main information sources include trade and production statistics, natural resource accounts, energy statistics, waste and emission statistics.

Most of the available information shows the monetary value and/or the physical quantity of natural resources being used in the economy. It answers questions about the magnitude of raw materials use and how it has changed over time, both absolutely and in relation to other commodities. It does however not give many insights about what happens to the various materials as they move inside and outside the economy, and how this relates to environmental risks and impacts and to resource productivity. It also does not provide information about the "unused" flows associated with the extraction of commodities, i.e. about materials that do not enter the economy as products but whose displacement can have adverse environmental effects. Gaps also remain as regards certain material resources, flows of secondary raw materials (recycled materials), and of recyclable materials, and overall resource use in the economy, as well as in the coverage of international resource flows, i.e flows among countries and different parts of the world, and their indirect implications in terms of natural resource use, pollution and waste induced by countries' demand for traded raw materials and products.

Information is therefore insufficient to give an coherent view of how different resources and materials flow through the economy (from their extraction or import to their final disposal). These information shortfalls have implications for the quality of policy debates on the management of natural resources and use of materials in the economy, and for the achievement of economically efficient and environmentally effective resource policies at all levels.

4. THE VALUE OF MATERIAL FLOW STUDIES

Material flow studies or Material Flow Analysis (MFA) are among the potentially most useful tools to address these information shortfalls and to guide decision making. (Chapter 2).

By making better use of already available production, consumption and trade data, as well as of environment statistics (on waste, emissions, etc.) and by improving the modelling capabilities, MFA helps to more fully assess the physical resource base of economic activities and the associated economic supply and demand issues. It also improves the understanding of the physical and environmental dimensions of a country's economic and social development over the short, medium, and long terms, and it helps identify unnecessary waste of natural resources, energy and materials in the economy or in process chains which would go unnoticed in conventional economic or environmental monitoring systems.

Material Flow Analysis (MFA) refers to the monitoring and analysis of physical flows of materials into, through and out of a given system (usually the economy). It is generally based on methodically organised **accounts** in physical units. It uses the principle of **mass balancing** to analyse the relationships between material flows (including energy), human activities (including economic and trade developments) and environmental changes.

Material flows can be analysed at various scales and with different instruments depending on the issue of concern and on the objects of interest of the study. The term MFA therefore designates a **family of tools** encompassing a variety of analytical approaches and measurement tools, including **accounts and indicators**.

The principles of MF studies and of statistical approaches towards material flow accounts and material balances date back to the 1970s. Since the mid 1990s MF studies have been receiving increasing interest: first as a field of research promoted by academics (research institutes, universities), environmental NGOs, and increasingly also statistical offices; second as policy and information tools to support integrated decision making in the fields of natural resource, pollution, waste and materials management (at business and government level) and to contribute to the debates about sustainability issues. Countries are also increasingly interested in using material flow studies to better support policies and decisions concerning economic growth, international trade and globalisation, technology development and innovation.

Much progress has been made in developing and harmonising methodologies for MFA, and practical applications have progressed (OECD 2008c). Work carried out has been covering different resource flows at different levels of detail. Among these are complete material flow accounts and indicators at the economy-wide level, that have been promoted through joint research efforts by Austria, Germany, Japan, the Netherlands and the United States involving governmental and non-governmental institutions (Matthews et al., 2000., Adriaanse et al., 1997), and through collaborative work in Europe carried out by Eurostat on methodological guidelines (Eurostat 2001) and by the European Environment Agency and its Topic Centre on Resource and Waste management. This is further supported with international work on Integrated Environmental and Economic Accounting (commonly referred to as SEEA)[3], and with OECD work on environmental indicators and on environmental accounting and material flows (OECD 2003a; OECD 2003b).

Despite significant advances, MFA remains a "young" tool. Countries are at a variety of stages in developing and using MFA. The status of their work, its characteristics and scope, purpose and policy use vary considerably. Some of this diversity is expected, for example in the coverage of natural resources or materials when it reflects the varying economic and environmental importance of a given resource or material flow for different countries. Other differences, such as those concerning the concepts and methodologies applied, point to the need for additional clarification and convergence.

The various MFA tools, their characteristics and levels of application are described in Chapter 3.

3 *Integrated Environmental and Economic Accounting 2003- Handbook on national accounting*, United Nations, European Commission, IMF, OECD, World Bank, 2003

Chapter 2.
ANALYSING MATERIAL FLOWS: A TOOL FOR DECISION MAKING

Analysing material flows

provides a holistic and integrated view of material flows through the economy that is useful for a variety of public and private policies

- **Economic, trade and technology development policies**
- **Natural resource management policies**
- **Environment policies**

ANALYSING MATERIAL FLOWS: A TOOL FOR DECISION MAKING[4]

Material flow analyses supported with regularly assembled MF accounts and indicators can be useful in a variety of public and private policy settings. Conversely they do not lead to any particular government policies. There are three broad policy areas in which material flow analyses are particularly useful. These policy areas overlap and are handled by many different government agencies, ministries and departments. They are all concerned in one way or the other by sustainable resource use. They include:

- Economic, trade and technology development policies.
- Natural resource management policies
- Environmental policies

Material flow accounts are not the only type of information tools available and needed to support analysis and decisions in these areas. But they are the only tools that:

- can provide a holistic and integrated view of resource flows through the economy,
- capture flows that do not enter the economy as transactions but that are important from an environmental point of view,
- help understand how flows of materials shift within countries and among countries and regions, and how this affects the economy and the environment within countries and abroad.

These characteristics make them a useful tool for examining trade-offs between policies and for understanding the implications of decisions that depend on interrelationships in the economy and the environment. They can be used to analyse issues that cut across different media and policy areas and support decisions that have economic, environmental and social implications.

To fully realise these benefits, the analysis needs to be well adapted to the country's specific circumstances and to the issues to be addressed. This leads to some diversity in the studies carried out and needs to be taken into account when comparing the results across countries.

The sections below give an overview of the type of insights that information systems based on MFA can provide and how this can contribute to informed decision making in each of the three policy areas. It has to be noted that not all links described here are straightforward, and that often the combined use of different information tools and analyses is recommended to secure all the insights needed.

4 This chapter builds on experience from practical applications and on surveys carried out in OECD countries. It draws in particular on the following documents and publications: OECD (2001), *Policies to enhance sustainable development*, OECD, Paris; OECD (2001), *Sustainable development - Critical issues*, OECD, Paris; US National Research Council (2004), *Materials count - The Case For Material Flows Analysis*; Derry Allen et al., (2005), *Material Flow Accounts*: *How they can be used as an information tool for the 21st century public policy*, Background paper, USEPA, Washington.

1. USEFULNESS FOR ECONOMIC, TRADE AND TECHNOLOGY DEVELOPMENT POLICIES

1.1. Economic aspects

Context

National and international economies operate on a foundation of several types of capital stocks that involve man-made[5], natural, human[6] and social[7] capital. Natural capital provides essential material and energy inputs and environmental services for economic production.

The availability of materials needed to support economic activity depends both on a country's endowment in natural resources and on the accessibility of external sources of material inputs (via imports). The extent to which this availability is a constraint for economic growth depends on the efficiency with which the resources are used and on a country's capacity to innovate and develop new technologies. At international level, the availability of materials is further influenced by their geographical distribution[8], by world-wide demands and market prices for materials, as well as by political, institutional and regulatory factors.

The regular compilation of national material flow accounts (MFAcc) provides physical information that parallels that of national economic accounts. It can be used in studies that give insights on how the economic performance can be improved by reducing energy and materials inefficiencies. This is also of value for technology development and innovation policies. The globalisation of the economy further means that understanding the flows of materials is essential to many trade and supply security decisions, and has a bearing on development co-operation and foreign investment decisions.

The value of MFA and related information systems

Information systems based on MFA can enhance the understanding of the material basis of the economy and give insights into the way economic policy interacts with natural resource and material flows. This is useful in particular where the spatial nature of the flows is not critical to the analysis[9]. They can for example be used to:

- Measure aspects of the physical performance of the economy and relate it to its economic performance. Here MFA is particularly useful when used in conjunction with other productivity measures and with economic modelling that enables a broad form of full-cost accounting on a range of scales.
- Monitor the materials requirements for activities designed to support economic growth that frequently involve construction, reconstruction, maintenance and disposal of infrastructure (e.g.

Useful tools
- Economy-wide MF analysis and accounts
- Input-output analysis and accounts

Examples
- United Kingdom: study by the business sector on iron, steel and aluminium (Biffaward Mass Balance programme)
- USA: WRI study
- European Union: Mosus project
- Germany: raw material productivity
- Japan: use of material flow accounts to calculate national resource productivity indicators in support of the Government's Fundamental Plan for establishing a sound material cycle society

5 Including the produced means of production like machinery, equipment and structures, but also non-production related infrastructures; cultivated assets such as livestock for breeding and vineyards; intangible assets such as computer software, entertainment, or cultural goods; and the financial assets that provide command over current and future output streams.
6 Including labour, skills, knowledge, competencies and other attributes embodied in individuals, the knowledge, skills, that facilitate the creation of wealth. Thus defined, human capital encompasses education (both formal and informal) and health.
7 Including the shared norms, values and social relations embedded in the social structures of societies that enable people to co-ordinate action to achieve desired goals.
8 When development relies heavily on a particular resource that is geographically concentrated (such as certain minerals or oil) this can put the supply of that resource to economic activities at risk (e.g. in case of political instability or weak governance, in case of natural disasters).
9 When the spatial nature of the flows is critical for the analysis, e.g. in the case of water flows, other tools are needed to give the necessary insights.

roads, buildings, utilities). Here MFA is particularly useful when used in conjunction with an analysis of the energy requirements of the same activities.

- Monitor the level of "decoupling" between economic growth and environmental pressures, i.e. the "decoupling'' of pollutant releases, waste, and primary resource inputs from economic output in all sectors. Decoupling is often best achieved with economic and environmental policies that favour actions that focus early in the life-cycle or the supply chain, in line with the shift from end-of-pipe to preventive management approaches.

At a more detailed level, MF analysis can also usefully contribute to studies designed to:

- Assess to what extent policies designed to stimulate economic growth can shift resource and environmental issues between world regions or countries, between different types of environmental media and over time.
- Help understand how legislation, government programmes and voluntary changes in material use impact on the design and use of particular products, and how this affects trade and supply patterns, technology developments and environmental conditions. Examples range from the very specific, such as regulations on the disposal of computers or the elimination of arsenic and mercury in consumer products, to the very general, such as changes that could result from energy efficiency programmes or a transition to a "hydrogen economy."
- Help understand the effects of subsidies and taxes on the price of a commodity and how this affects the entire flow of that commodity, from extraction through manufacturing, product use, reuse/recycling and disposal.
- Help identify the best opportunities for internalising adverse external effects and support the application of the polluter pays principle (PPP).
- Assess the economic benefits and costs to keeping materials in the active materials stream and minimising the amounts of waste materials going to final disposal by seizing opportunities for efficiency gains, energy and material recovery, and improving resource productivity.

1.2. Trade aspects & supply patterns

Context

Changes in world-wide demand for materials to support OECD economies as well as fast-growing and emerging economies have consequences for the global economy, trade and environment. International markets for materials and products are expanding and becoming more complex, with increasing international flows in goods and materials, increased mobility of production factors, and expanding linkages amongst developed and developing countries. What happens in one country has important effects in other countries. Regional specialisation for example makes production processes in OECD and many other countries becoming more dependent on external sources of inputs and/or on demands in markets located in other countries.

Shifts in flows of a given material can also affect the amount and origin of flows of by-product materials whose supply may be important for an economy and whose production and use may in turn raise environmental or health questions (e.g. copper, and molybdenum as a by-product of copper mining).

This brings about questions about the effects of national material requirements and consumption on the environment and human health in countries abroad. Expanding flows and linkages among countries also raise questions as to the environmental risks related to international transport of goods and materials, including dangerous goods and hazardous waste (by sea, air, inland water, road, pipelines). The effects of changing international flows of materials, be they environmental, social or

economic, need to be well understood and taken into account as aspects of international trade and development.

The origin and destination of international flows of materials and the associated economic, social and environmental impacts are affected by many factors, among which:

- Foreign outsourcing and the relocation of production for semi-finished and finished goods;
- Trade measures and agreements, and
- Environmental measures and agreements[10].

The value of MFA and related information systems

Information systems based on MFA show the relationships between elements of international markets, and highlight the role of the rest of the world (i) as a user of the raw materials, goods and services supplied by a country and (ii) as a provider to fulfill a country's demand for raw materials, goods and services. They give insights into the opportunities for national economies in a global market to help avoid supply disruptions, and help analysing the resiliency of the international economy and the effect of changes in worldwide demand for various materials on the global economy and environment.

This often requires using detailed MFA that not only capture domestic interaction, but also interactions among countries. It requires in particular connecting MFAcc with monetary I-O tables and related analysis that enable the estimation of indirect flows associated to traded products[11]. The results can then be used to:

- Support structural analysis of the global economy in physical terms, i.e.: analyse how globalisation, foreign outsourcing and relocation of production affect international flows of materials, and get insights into (i) the substitution of domestically produced raw materials, goods and services with imported raw materials, goods and services, (ii) how this interacts with production and consumption patterns and (iii) what the environmental consequences are.
- Monitor the structural effects of trade and environment measures on international materials markets and on flows of environmentally significant materials (e.g. hazardous materials or waste; secondary raw materials, recyclable materials; renewable materials from certified cultivation).
- Monitor the environmental implications of changes in international material flows, including (i) environmental pressures from indirect flows abroad associated to traded products (e.g. pollutant emissions, resource use); (ii) environmentally significant materials included in imported goods (e.g. heavy metals, hazardous chemicals); (iii) environmental risks related to international transport of materials, etc.

Useful tools

- Economy-wide MFA with an appropriate coverage of trade flows by origin and destination
- Environmental input-output analysis
- Physical and monetary input-output tables
- International input-output tables
- Hybrid approaches combining physical and monetary analysis
- International trade statistics

Examples

- Japan: study on world resource flows around Japan (e.g. aluminium flows and associated CO_2 emissions).
- Italy: research study on indirect material flows associated with imports

[10] Environmental measures play a role for example when materials are imported from abroad to comply with national environmental regulations and standards, or when international movements of reused goods or recyclable materials change due to measures linked to production processes, or to waste or product policies.

[11] See also OECD (2007), OECD (2008).

1.3. Technology development aspects[12]

Context

Technology developments and innovation are important factors in the growth and the productivity of an economy. They are also important in managing material flows successfully and have a bearing on policies intended to preserve natural resources and materials and minimise the pollution burden. Innovation in new technologies has an important role to play to support moves in environmental policies towards more integrated and result-oriented approaches to materials production and management. Innovation in education and governance structures has an important role to play to support moves towards new management methods, greater transparency in decision making, the adoption of co-operative approaches and partnerships, and the diffusion of knowledge.

If well steered and managed, technological progress may in the longer term help breaking the link between economic growth, increases in resource consumption and environmental degradation. A number of new or nascent technologies have the potential for increasing the efficiency of material resource use by creating opportunities to reduce primary resource use and wastes, and use alternative materials (e.g. nano-technology, applications of superconductivity, new materials manufacturing; new energy technologies; innovative waste treatment and recycling technologies, cleaner production technologies).

At the same time, many new technologies have the potential to generate additional environmental pressures or to strain material availability. New technologies frequently involve the use of new materials or the substitution of materials and the consequences of using these new materials need to be known. The same applies to the development and marketing of many new products that have consequences on air pollution, chemical safety and recyclability, as well as on disposal problems at end of life. All these externalities and their consequences need to be understood and addressed. This is also of interest to environmental policies. (section 3).

The value of MFA and related information systems

Information systems based on MFA are useful to better understand the economic, material, energy, health and environmental implications of new technologies. This usually requires fairly detailed MFAcc and subsequent analysis, sometimes at the product level and combined with an analysis of the respective value chains. Practical applications are not yet well developed, but experience so far suggest that the results from MFA can support studies that are designed to:

- Guide the development of new technologies and help "prevent" technologies that would severely strain material availability or generate excessive additional environmental pressures.
- Identify potential areas for research on substitutions of materials and on the availability of materials for the development of new technologies.
- Identify the technological issues underlying environmental problems.
- Detect opportunities for developing new technologies that help reduce inefficiencies in energy and materials use, and increase the domestic reuse or recycling of certain materials and the use of alternative materials, and hence improve the supply security.

Useful tools
- ♦ Material system analysis and resource specific material flow accounts
- ♦ Life cycle analysis of products
- ♦ Value chain analysis

Examples
- ♦ Japan: use of MFA in the automobile industry (Toyota Motor Corporation)
- ♦ United Kingdom: studies by the business sector on various material flows (Biffaward, Mass Balance programme)

12 OECD (2001), *Sustainable development - Critical issues*, Chapter 6 Technology, OECD, Paris.

2. USEFULNESS FOR NATURAL RESOURCE MANAGEMENT POLICIES[13]

Context

Natural resources are a major foundation of economic development. Their stocks are an integral part of larger ecosystems, and when depleted or degraded, cannot easily be restored or replaced. Their importance for economic development and the environment varies depending on the type of resource and its natural stocks. Resources from non-renewable natural stocks such as metal ores and other mineral resources or fossil fuel carriers for example underpin much economic activity, but their environmental role and non-market values prior to extraction are lower than those of resources from renewable natural stocks that fulfil in addition important ecosystem and amenity functions.

The way natural resources and materials are managed and used all way through the economy is crucial for ensuring adequate supplies of materials to economic activities, managing the environmental impacts associated with their extraction, processing, use and disposal, maintaining non-commercial environmental services and preventing resource degradation and depletion.

- Preservation and sustainable use of resources from renewable natural stocks helps maintain an appropriate level of regeneration and natural productivity, and minimise pollution and waste associated with their extraction and economic use. It further helps support the provision of recreation and non-market ecosystem services.
- Preservation and sustainable use of resources from non-renewable natural stocks helps avoid excessive resource depletion and supply disruptions in the longer term; and minimise pollution and waste associated with their extraction and economic use. It further helps support the substitution of materials.

At international level, the adoption and implementation of good governance principles in the field of natural resource management and raw materials production can help ensure adequate supplies of natural resources in future, reduce price uncertainties for important industrial raw materials, and promote transparency and accountability over natural resource revenues[14].

The value of MFA and related information systems

Information systems based on MFA complement and enrich conventional natural resource and energy accounts by providing system-wide lifecycle information on the status and trends of natural resources. Such information can be used to encourage more sustainable use of resources and to integrate the work of different agencies and sectors managing the same natural resource or resources whose management has implications for other resources. It is also of relevance to integrated pollution prevention and control and to policies related to waste and sustainable materials management (section 3).

Useful tools

- Material system analysis and resource specific material flow accounts
- Natural resource accounts: asset and flow accounts

It has to be noted that, though MFA usually focuses on material resources other than water, MFA can equally be applied to water resources and be used to support the implementation of effective water management strategies at various levels.

13 OECD (2001), *Policies to enhance sustainable development*, Chapter 7. Managing Natural Resources, OECD, Paris..

14 See for example the Extractive Industries Transparency Initiative (EITI, www.eitransparency.org), launched as a complement to G8 efforts to fight corruption and improve transparency (G8 summit, Evian, 2003), and the G8 discussion on the security of global raw materials supply and related governance issues (G8 summit, Heiligendamm, 2007).

Specifically, information from MFA can be used to:

- Assess the status of a country's natural resources, including forecasts of demand for and supply of renewable and non renewable resources. When paired with other information from natural resource accounts, it helps monitor and determine sustainable production levels (e.g. in the field of forestry and forest resources) and support related management plans cutting across different policy areas and economic sectors.
- Answer questions about demand, scarcity and raw material requirements, based on the full cycle of materials use and understand what is behind price and production trends in mineral, forest or agricultural commodities over extended periods of time. This requires a combination of MF data with data from natural asset accounts and information on available proven reserves, economically demonstrated reserves and rates of discovery.
- Assess the status and trends of mineral systems by tracking raw materials used in the economy, and by describing the flow of a specific material within the economy as a commodity and the flow of different materials as a product, and by helping better understand the amount and trends of material stocks in use, reuse and disposal in a country.
- Assess the status and trends of energy systems by tracking energy carriers used in the economy. The energy part of an MFA database complements conventional energy accounts and statistics by giving further insights into the non-fuel uses of fossil fuels (e.g. plastics, synthetic fibres), and by emphasising multiple uses. MFA databases can further be used to link energy accounts to air emission or greenhouse gas inventories.

Examples

- Australia: Accounting for water resources to support negotiations on water allocation.
- USA: studies of world metal flows (copper, zinc, silver, nickel, etc.) by the Yale University, Stock and Flows project
- Japan: Material and carbon flows of harvested wood
- Canada: Material and Energy flow accounts

3. USEFULNESS FOR ENVIRONMENTAL POLICIES

Context

Environmental policy has long targeted individual pollution sources and pollutants, supported with media-oriented environmental information and with end-of pipe pollution control. Countries now have moved towards more result-oriented policies, with greater emphasis on preventive and integrated approaches, increased use of cleaner technologies and of mixes of policy instruments. Examples of preventive and integrated policies include: integrated pollution prevention and control (IPPC), ecosystem based water management, integrated product management, green purchasing policies, sustainable building, and sustainable materials and waste management as reflected in 3R "reduce, reuse, recycle" programmes and in circular economy initiatives*.

Conventional media-oriented environmental information alone is often insufficient to offer policymakers all the insights needed to support integrated management approaches and to measure progress that goes beyond separate problems. Pollutant release and transfer registers (PRTR) address some of these gaps by tracking the movements of hazardous materials, including certain releases to the environment. But they do not cover releases over the entire material or product cycle, nor flows that do not become releases to the environment. Information from environmental impact assessments gives insights into relative environmental impacts of certain policies or projects and into the location of these impacts. Waste statistics offer insights into the generation, treatment and disposal of waste

*3R and circular economy initiatives aim at closing materials loops and extending the lifespan of materials through longer use and the increased use of secondary raw materials. These initiatives also aim at material substitution: the use of materials with smaller environmental impact, and replacing the environmentally most damaging materials.

material flows, including recovery and recycling efforts. They do however not cover materials or products before they become waste, and cannot easily be linked to primary resource use.

The value of MFA and related information systems

Information systems based on MFA complement and enrich conventional media based environmental information systems: they facilitate analyses that make it possible to compare between environmental releases associated with different stages of a particular material flow (e.g. releases from extraction or production versus use or disposal) or associated with the flows of different materials. Such analyses help understand the underlying causes of environmental burden from a systems perspective and develop ways to prevent environmental problems, reduce inefficiencies in materials use and improve resource productivity.

This is particularly useful for policies and decisions related to the control of toxic substances, IPPC, natural resource conservation, and waste and sustainable materials management. It provides a basis for developing materials-, product- or industry-based environmental strategies. It also provides a basis for analysing interrelated problems and policies, and for promoting the integration of environmental concerns into other policy areas (economy, trade, science and technology, natural resource management, etc.).

Useful tools

- Economy-wide MFA with detailed breakdown of materials for input and output flows
- Substance flow analysis
- Material system analysis and material specific flow accounts
- Life cycle analysis of products
- Waste statistics and accounts

To be suitable for the purposes of materials, waste and pollution management, the underlying accounts must provide extensive and detailed information, often at the level of particular materials or substances, that can be combined with information from environmental monitoring systems and with environment statistics such as waste statistics.

3.1. Identify system-wide sources of pollution and opportunities for pollution prevention

Specifically, information systems based on MFA can be used to identify system-wide sources of pollution and point at opportunities for pollution prevention throughout the resource cycle of a particular material or substance. They can in particular:

- Map and understand the flows of nutrients, contaminants or toxic substances in a given region, country or river basin and identifying whether, where and to what extent these flows contribute to environmental degradation "downstream". This is of interest to policies and decisions related to the control of fertilizers, chemicals or hazardous substances (e.g. heavy metals, pharmaceuticals, hormones). It generally requires a substance flow analysis.
- Estimate the environmental pressure from the extraction and production of metals (e.g. copper, iron, aluminium), the part of the pressure due to inefficiencies in production technologies, the part of the pressure that could be reduced through appropriate reuse and recycling of metals, and the benefits that could be gained from new technologies. This is equally of interest to natural resource management policies (section 2).
- Monitor and help understand indirect and unused flows and their effects on the environment, at home and abroad. This is also of interest to trade and development policies.

Examples

- Sweden: study of mercury, lead and copper flows in the Stockholm area
- Sweden: study on chemical products in industry
- Denmark: mass flow analyses of mercury (project financed by the Danish EPA)
- United States: study of heavy metals and other hazardous substances in the New York/New Jersey harbour
- United States: mapping of nitrogen flows in the Mississippi Basin (USGS)
- United States: study on chlorine flows (research project, Yale University)

3.2. Identify system-wide waste of materials and opportunities for efficiency gains

Information systems based on MFA can be used to help identify waste of materials, including energy, in the economy or in process chains, which go unnoticed in conventional monitoring systems, and analyse opportunities for efficiency gains at the various stages of the extraction and production chain. In particular:

- Identify and analyse trends in waste generation, and how they affect opportunities for (i) resource conservation and resource productivity, and (ii) material recovery and recycling. This requires a combination of MF information with waste statistics (including reliable recycling data), and MFAcc that distinguish between different material classes and between primary raw materials, recyclable materials and secondary raw materials.
- Identify areas for research for (i) energy conservation and recovery, (ii) materials recycling, (iii) the use of alternative materials and (iv) the development of new technologies.

Examples

- ♦ Japan: use of material flow accounts to calculate waste and recycling indicators in support of the Government's Fundamental Plan for establishing a sound material cycle society
- ♦ Austria: use of material balances and life-cycle analysis to determine the effects of product re-use on resource conservation (applied to electrical and electronic household appliances)
- ♦ Norway: waste accounts
- ♦ United Kingdom: studies by the business sector, (Biffaward, mass balance programme.

3.3. Characterise products and identify opportunities for efficiency gains and pollution prevention

Information systems based on MFA can also be used to characterize products and their uses, and identify opportunities for efficiency gains and minimising waste and pollution associated with all stages of a product's live from material extraction to disposal. This can be based on a combination of life cycle analysis (LCA) with broader MF information systems. When paired with economic data it further enables cost/benefit analyses of options for materials to be used in products. Specific uses include:

- Examining source reduction, substitution, and recyclability of the materials composing a product and help understand the synergistic nature of the flows of these materials.
- Examining the environmental impacts that products can have, in particular products with toxic ingredients (e.g. lead paint, asphalt roofing, batteries with cadmium).
- Exploring design issues that affect the environment at end of product life (e.g. electronic equipment), and identifying leverage points for eco-design (design for environment, design for recycling, etc.) and pollution prevention at different scales (plant, product, city, etc.), and implications of a policy shift (e.g. limiting or banning the use of certain materials in particular products).

3.4. Other environmentally relevant applications

Information systems based on MFA can also contribute to studies that:

- Identify certain types and quantities of chemicals at a site, measure source reduction and recycling, and verify quantities reported in PRTRs. This is of interest to businesses and local authorities.
- Analyse the effects of environmental policy instruments on material flows and the supply mix.
- Assess the economic benefits and costs to keeping materials in the active materials stream and to minimising the amounts going to final disposal, and assess developments in markets for reused and recyclable materials.
- Determine whether and where government purchasing policies can be of benefit (e.g. as regards the availability of recycled or redesigned products to the market), and what the overall effects on material flows are.
- Monitor environmental performance targets with industry and government, for example when MFA is made part of the Environmental Management Systems of a company or for government operations. This is of interest to business strategies and to government green purchasing policies.

Table 1. Applicability of MFA to policy making

Policy areas		Relevant MFA functions	Appropriate MFA tools	Examples of applications
Economic, trade and technology development policies	Economic policies	♦ Measure aspects of the physical performance of the economy and relate it to its economic performance. ♦ Analyse the materials requirements for activities that involve construction, reconstruction, maintenance and disposal of infrastructure. ♦ Measure the degree of "decoupling" between direct and indirect environmental pressures (pollution, waste, primary resource inputs) and economic growth	♦ Economy-wide MFA ♦ Physical I-O analysis *In conjunction with*: ♦ Productivity measures ♦ Economic modelling ♦ Analysis of energy requirements	*United Kingdom*: business sector study on iron, steel and aluminium flows (Biffaward Mass Balance programme); *USA*: WRI study; *Austria*: study on the economic and employment effects of resource savings *Germany*: raw material productivity; PIOTs *European Union*: Mosus project; *Japan*: national resource productivity indicators in support of the Government's Fundamental Plan for establishing a sound material cycle society
	Trade aspects & supply patterns	♦ Support structural analysis of the global economy in physical terms: effects of globalisation on international material flows; substitution of domestic raw materials with imported ones; interaction with production & consumption patterns. ♦ Monitor the structural effects of trade and environment measures on international materials markets and on flows of environmentally significant materials (e.g. hazardous materials; secondary raw materials, recyclable materials). ♦ Monitor the environmental implications of changes in international material flows, including (i) environmental pressures from indirect flows abroad associated with trade; (ii) environmentally significant materials embedded in imported goods; (iii) environmental risks related to international transport of materials, etc.	♦ Economy-wide MFA covering trade flows by origin/destination; ♦ Physical I-O analysis; ♦ Environmental I-O analysis; *In conjunction with:* ♦ Monetary I-O tables; ♦ International trade statistics; ♦ International transport statistics.	*Japan*: study on world resource flows around Japan (e.g. aluminium flows and associated CO2 emissions); *Italy*: research study on indirect material flows associated with imports *European Union*: research study on environmental impacts of natural resource trade flows into the EU
	Technology development	♦ Guide the development of new technologies and identify those that would severely strain material availability or generate excessive additional environmental pressures. ♦ Identify potential areas for research on substitutions of materials and on the availability of materials for the development of new technologies. ♦ Detect opportunities for new technologies that help reduce inefficiencies in energy and materials use, increase domestic reuse or recycling and the use of alternative materials.	♦ Material system analysis and material specific accounts; ♦ Life cycle analysis of products *In conjunction with:* ♦ Value chain analysis	*Japan*: use of MFA in the automobile industry and in other industries (iron&steel, cement, chemicals, paper, construction, home appliances); *United Kingdom*: studies by the business sector on various material flows (Biffaward, Mass Balance programme).
Natural resource management policies		♦ Assess the status and trends of a country's natural resources. Monitor sustainable production levels (e.g. forest resources) and support related management plans. ♦ Examine the demand, scarcity and raw material requirements, based on the full material cycle and understand what is behind price and production trends in commodities over extended periods of time. ♦ Assess mineral systems by tracking (i) raw materials used in the economy, (ii) the flow of a specific material in the economy as a commodity (iii) the flow of different materials as a product, (iv) material stocks in use, reuse and disposal in a country. ♦ Assess energy systems by tracking energy carriers used in the economy, by giving insights into multiple uses, including non-fuel uses (e.g. plastics, synthetic fibres).	♦ Material system analysis and resource specific accounts; *In conjunction with:* ♦ Natural resource accounts ♦ Information on proven reserves and rates of discovery. ♦ Energy accounts and statistics ♦ Modelling	*Australia*: Accounting for water resources to support negotiations on water allocation. *USA*: studies of world metal flows (copper, zinc, silver, nickel, etc.) by the Yale University, Stock and Flows project. *Japan*: Material and carbon flows of harvested wood. *Canada*: Material and Energy flow accounts

Policy areas		Relevant MFA functions	Appropriate MFA tools	Examples of applications
Environmental policies	Pollution prevention & control	♦ Map the flows of nutrients or contaminants in a region, country or river basin and identify whether, where and to what extent these flows contribute to environmental degradation "downstream". ♦ Estimate environmental pressures from metal ore extraction and metal production, the part due to inefficiencies in production technologies and the benefits that could be gained from new technologies and from improved recovery and recycling. ♦ Monitor and help understand indirect and unused materials flows and their effects on the environment, at home and abroad.	♦ Economy-wide MFA with detailed breakdown of materials. ♦ Substance flow analysis. ♦ Material system analysis and material specific accounts. *In conjunction with:* ♦ Waste statistics & accounts	*Sweden*: study of mercury, lead and copper flows in the Stockholm area. *Sweden*: study on chemical products in industry. *Denmark*: mass flow analyses of mercury (project financed by the Danish EPA). *USA*: study of heavy metals and other hazardous substances in the New York/New Jersey harbour. *USA*: mapping of nitrogen flows in the Mississippi Basin (USGS). *USA*: study on chlorine flows (research project, Yale University).
	Waste and materials management	♦ Analyse trends in waste generation, and how they affect opportunities for (i) resource conservation, (ii) resource productivity, and (iii) material recovery and recycling. ♦ Assess the economic benefits and costs to keeping materials in the active materials stream and to minimising the amounts going to final disposal. ♦ Assess developments in markets for reused and recyclable materials. ♦ Identify areas for research on (i) energy conservation and recovery, (ii) materials recycling, (iii) alternative materials and (iv) new technologies.	♦ Various MFA tools distinguishing between primary and secondary raw materials, and recyclable materials. *In conjunction with:* ♦ Waste statistics & accounts ♦ Cost benefit analysis ♦ Modelling	*Japan*: waste and recycling indicators in support of the Government's Fundamental Plan for establishing a sound material cycle society. *Austria*: use of material balances and life-cycle analysis to determine the effects of product re-use on resource conservation (applied to electrical and electronic household appliances). *Norway*: waste accounts. *United Kingdom*: business sector studies, (Biffaward, mass balance programme).
	Product related policies	♦ Examine source reduction, substitution, and recyclability of the materials composing a product and help understand the synergistic nature of the flows of these materials. ♦ Examine environmental impacts of products, in particular products with toxic ingredients (e.g. lead paint, asphalt roofing, batteries with cadmium). ♦ Explore design issues that affect the environment at end of product life, and identifying leverage points for green design and pollution prevention, and implications of a policy shift (e.g. ban on use of certain materials in particular products).	♦ Life cycle assessments	*Many applications (business sector, research institutes, government departments)*
	Other	♦ Analyse the effects of environmental policy instruments on material flows and on the material supply mix. ♦ Analyse the benefits of government purchasing policies (e.g. for the availability of recycled or redesigned products to the market), and how they affect material flows ♦ Monitor environmental performance targets with industry and government.	♦ Various MFA tools *In conjunction with:* ♦ Cost benefit analysis ♦ Modelling ♦ EMS	

Source: OECD.

Chapter 3.
OVERALL FRAMEWORK FOR MATERIAL FLOW ANALYSIS

Material flow analysis:

a multi-purpose family of tools
using the principle of mass balancing
to study how materials flow through the economy
and the environment within countries and among
countries.

- **Characteristics and conceptual foundations**
- **Architecture and levels of application**
- **Analysing material flows at macro-level**
- **Analysing material flows at meso-level**
- **Analysing material flows at micro-level**

OVERALL FRAMEWORK FOR MATERIAL FLOW ANALYSIS[15]

1. CHARACTERISTICS AND CONCEPTUAL FOUNDATIONS

1.1. Characteristics

Material Flow Analysis (MFA) refers to the monitoring and analysis of physical flows of materials into, through and out of a given system (usually the economy), and is generally based on methodically organised accounts in physical units. It analyses the relationships between material flows, including energy, human activities – including economic and trade developments – and environmental changes. Material flows can be analysed at various scales and with different instruments depending on the issue of concern and on the objects of interest of the study.

Levels of application and functions

MFA can be applied to a wide range of economic, administrative or natural entities, studying the flows of materials within the global economy or within the economy of a region or a country, within a territory, a municipality or a city, within a natural unit, such as a river basin or an ecosystem, within an economic activity or an industrial unit such as a firm or a plant.

At each of these levels, MFA helps understand the flows of natural resources and materials, their shifts and their economic and environmental implications. It helps locate the sources of environmental stress, identify risks of supply disruptions, identify opportunities for efficiency and productivity gains, and formulate ways to manage, control and reduce the adverse environmental impacts of resource use. This is of value in many policy areas and business strategies, especially in a context of population growth, economic and technological changes, with pressures to use resources in a way that is both economically efficient and environmentally effective (Chapter 2).

Materials, products and substances

A material flow study can in principle cover any possible relevant set of materials at various levels of detail, from the complete collection of all resources and products flowing through the system under analysis to groups of materials at various levels of detail and to particular products. It can also be applied to particular materials or even single chemical elements that raise specific concerns as to the sustainability of use of the original natural resource, as to the environmental implications of their use or as to their economic or trade implications. A distinction often found in MF studies is between material and substance flows, where substances tend to mean 'pure' chemical elements or compounds (e.g. heavy metals, chlorinated chemicals) and materials the actually observed flows of raw materials, underlying natural resources, products and residuals which are often, but not always, a mixture of various substances (e.g. fuels, water, timber, plastics, non-ferrous metals, total material throughput).

Water is a case apart. Because of their significant weight, water resources are usually not included in material flow studies that analyse the total material flows of an economy. Including water in these studies would completely mask developments in other materials. Water flows are rather analysed separately as part of specific studies based on water flow accounts that can use the principles and concepts of material flow analysis.

[15] This Chapter builds on contributions by Derry Allen, Stefan Bringezu, Aldo Femia, Yuichi Moriguchi, and Heinz Schandl; and on Eurostat (2001).

A family of tools

The term MFA has long been used to designate economy-wide MFA that covers the entire range of materials exchanged at the boundary of the national economy and whose results can be used to provide an aggregate overview of annual material inputs and outputs of an economy. This definition does however not reflect the diversity of instruments that can be used to analyse material flows at various scales. In this guide the term MFA therefore designates a family of tools making reference to the materials balance principle, encompassing a variety of analytical approaches and measurement tools at different levels of detail and completeness, ranging from economy-wide MFA to substance or product specific analysis and input-output analysis. Each type of analysis is associated to MF accounts or other measurement tools, and can be used to derive various types of indicators (section 2.1).

Material flow accounts (MFAcc)

… are important for structuring the information basis that is needed to carry out material flow analysis. Like other accounts, MFAcc are descriptive, not normative. They are a special application of physical flow accounts as described in the System of integrated Environmental Economic Accounting (SEEA). They form a basis for many types of analysis and evaluation and enable the calculation of various types of indicators. (Chapter 5).

Material flow indicators

… are important for measuring progress with resource productivity and materials use, and for communicating the results of MF studies to a non expert audience (general public, high-level decision makers, policy analysts, etc.). (Chapter 4)

1.2. Conceptual foundations

The principle of mass balancing and the first law of thermodynamics

MFA uses the principle of mass balancing to study how materials and energy flow through the economy and the environment within countries and among countries. It is based on the fact that raw materials, water and air are extracted from the natural system as inputs, transformed into products and finally re-transferred to the natural system as outputs (in the form of waste and emissions).

The accounting concepts involved are founded on the first law of thermodynamics (called the law of conservation of matter), which states that matter (mass, energy) is neither created nor destroyed by any physical process. This leads to the following accounting identity:

natural resource extraction + imports = residual output + exports + net addition to man-made stocks

*i.e. the sum of **material inputs** into a system equals the sum of its **material outputs**, thereby comprising the materials accumulated as **changes in stocks**.*

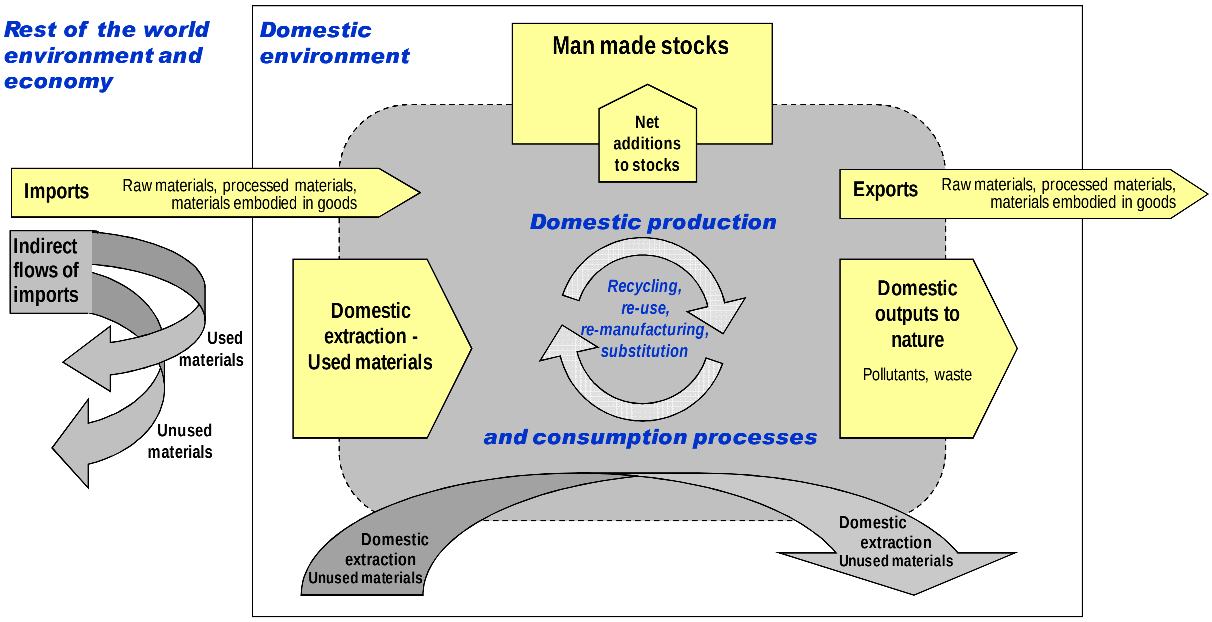
From a conceptual point of view, MFA is closely linked to the concepts of industrial ecology or the industrial metabolism[16] and shows similarities with concepts that underlie asset balances for environmental capital (e.g. genuine savings) or to some extent ecological footprints.

A holistic approach

The most complete applications of MFA take a holistic approach and are based on the assumption that every movement or transfer of materials or energy from one place to another has repercussions on the environment and has the potential to alter the environmental balance. This is why these applications pay great attention to what is called the unused and indirect flows of materials. These are flows that are of relevance from an environmental point of view because they can add to the pollution burden, disrupt habitats or alter landscapes, but that do not enter the economy as priced goods. A prominent example is mining overburden that can be significantly higher than the actual amounts of the desired mineral ore extracted. Further examples are the pollutants and wastes generated upstream in a production process and that occur outside the system under review, i.e the national economy or an industry. Much of these flows are hidden and never seen in economic accounts or in trade and production statistics. (Figure 1).

[16] Terms such as industrial metabolism or societal metabolism suggest considering modern economies as living organisms whose dominance in, and impact on, a given ecosystem can be indicated by the size and structure of its metabolic profile.

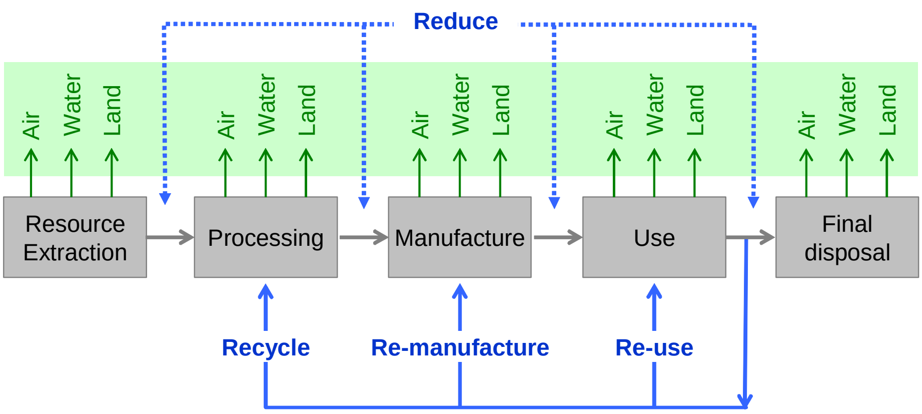
Figure 1. Schematic representation of an economy-wide material balance scheme



- Material resources used in an economy stem from raw materials extracted from natural resource stocks in the country (domestic material extraction) or extracted from natural resource stocks abroad and imported in the form of raw materials, semi-finished materials and materials embodied in manufactured goods.
- Material resources are extracted from the sub-soil and water bodies, or harvested from forests and farm land. The usable parts of these resources enter the economy as material inputs where they become priced goods that are traded, processed and used. Other parts remain unused in the environment. These materials are called "unused materials" or "unused extraction". Examples include mining overburden, soil and rock excavated during construction and not used elsewhere, dredged sediments from harbours, harvest residues.
- Some materials accumulate in the economy where they are stored in the form of buildings, transport infrastructure or durable and semi-durable goods, such as cars, industrial machinery or household appliances. These materials are sooner or later released back to the environment in the form of demolition waste, end-of-life vehicles, e-waste, bulky household waste, etc.
- After use in production and consumption activities, the materials leave the economy as an output either to the environment in the form of residuals (pollution, waste), or to the rest of the world as exports in the form of raw materials, semi-finished materials and materials embodied in manufactured goods.
- When materials are imported for use in an economy, their upstream production is associated with unused materials that remain abroad, and with the generation of residuals (pollution, waste). These "indirect flows" of materials take into account the life-cycle dimension of the production chain, but are not physically imported. Their environmental consequences occur in countries from which the imports originate.

Source: OECD.

Figure 2. Schematic representation of material flows through the commercial life-cycle



Source: OECD, adapted from Derry Allen, U.S. Environmental Protection Agency.

1.3. Terminology and language conventions

Work on MFA has generated a special terminology that is however not always used in a consistent way nor well understood by non-experts. This guide uses the following basic language conventions:

Material Flow Analysis (MFA)	The abbreviation MFA stands for the terms "material flow analysis"; it is used in a generic way and encompasses all tools of the MFA family, including accounts, indicators and analytical approaches.
Material Flow Accounts (MFAcc)	The abbreviation MFAcc stands for the terms "material flow accounts" or "material flow accounting"; it covers all types of accounts that quantify and describe the flows of material resources by making reference to the material balance principle, whatever the level of detail or aggregation is.
Materials or material resources	The term "materials" or "material resources" designates the usable materials or substances (raw materials, energy) extracted from natural resources. These usable "materials" include energy carriers (gas, oil, coal), metal ores and metals, construction minerals and other minerals, soil and biomass. In the context of MFAcc, the term "materials" is used in a very broad sense so as to record all material related flows at all relevant stages of the material cycle. It designates renewable and non-renewable natural resources that are used as material inputs into human activities and the products that embody them, as well as the residuals arising from their extraction, production and use (such as waste or pollutant emissions to air, land, water) and the ecosystem inputs required for their extraction, production and use. Air as a resource is not the object of MFAcc. Water as a resource is a case apart: because of its properties and its significant weight, it is reported in separate accounts. It is usually not included in so-called economy-wide MF accounts.
Substances	The term "substances" is used to designate 'pure' chemical elements or compounds (e.g. heavy metals, chlorinated chemicals, CO_2) that have been identified to raise particular environmental concerns.
Hidden flows	The term "hidden flows" is used to designate (i) the movements of unused materials associated with the extraction of raw materials from natural resources, both nationally and abroad, intended for use in the national economy; and (ii) the indirect flows of materials such as pollution or waste that occur upstream in a production process but that are not physically embodied in the product itself. The word "hidden" reflects the fact that these flows usually do not appear in traditional economic accounting. Since indirect flows are often difficult to estimate, the term "hidden flows" is used sometimes to designate "unused extraction".
Black box	The term "black box" is used in material flow accounting to characterise the system under scrutiny when the purpose is to record flows that cross the system boundary and not flows that are internal to the system. In national economy-wide material flow accounting for example the term "black box" is used to characterise the whole economic system, reflecting the fact that only flows crossing the system boundary between the national economy and the environment and between the national economy and the rest of the world are recorded (called throughputs).
National versus economy-wide	The term "national" is used to designate MFA tools that cover all human activities taking place within the national boundaries of a country, i.e. the national economic system, whatever the level of detail of the analysis is. The term "economy-wide" is used to designate MFA tools that cover the entire range of materials exchanged at the boundary of the national economy and whose results can be used to provide an aggregate overview of annual material inputs and outputs of an economy.
Complete	The term "complete" is used to qualify MFA tools that cover the entire range of materials exchanged at the boundary of the system studied, whatever the level of detail of the analysis is (individual materials or substances, groups of materials, aggregate amount of materials).

A full list of terms and definitions is given in the glossary of terms related to MF and resource productivity.

2. ARCHITECTURE AND LEVELS OF APPLICATION

2.1. Material flow related analyses and associated issues of concern

The different tools of the MFA family can be characterised according to the type of analysis carried out, the issues of concern and the questions addressed, and the level of detail, scale of application and specification of the flows under analysis. Six types of analysis can be identified. (Table 2).

The first group of analyses (type I) focuses on specific concerns related to environmental impacts, supply security and technology development that are associated to certain substances, materials and manufactured goods. It includes:

Ia	**Substance flow analysis (SFA)**	Substance flow analysis and accounts (SFA) monitor flows of individual substances (e.g. cadmium, lead, nitrogen, CO_2) that are known for raising particular concerns as regards the environmental and health risks associated with their production and consumption.
Ib	**Material system analysis (MSA)**	Material system analysis (MSA) is based on individual material flow accounts. It focuses on selected raw materials or semi-finished products at various levels of detail and application (e.g. cement, paper, iron and steel, copper, plastics, timber, water) and considers life-cycle-wide inputs and outputs.[17] It applies to materials that raise particular concerns as to the sustainability of their use, the security of their supply to major economic activity sectors, and/or the environmental consequences of their production and consumption.
Ic	**Life cycle assessments (LCA)**	Life cycle assessments (LCA) are based on life cycle inventories. They focus on materials connected to the production and use of specific products, i.e. manufactured goods (e.g. batteries, cars, computers, biofuels, textiles), and analyse the material requirements and potential environmental pressures along the full life cycle of the products. LCA can equally be applied to services, and are standardised in ISO 14010.

The second group of analyses (type II) focuses on general environmental and economic concerns related to the flows of materials through a given system (called throughputs) at the level of specific businesses, economic activity sectors, countries or world regions. It includes:

IIa	**Business level MFA**	Business material flow analysis and accounts monitor material flows at various levels of detail for a company, a firm or a plant.
IIb	**Input-Output analysis (IOA)**	Input-Output analysis (IOA) is based on physical input-output tables (PIOTs) that record material flows at various levels of detail to, from and through the economy broken down by economic activity and final demand category. It can also make use of the physical flow part of Hybrid flow accounts (HFA) such as NAMEA-type tables[18] that record the flows of specific materials (e.g. waste, energy carriers, air pollutants) to and from the economy broken down by economic activity and consumption function.
IIc	**Economy-wide material flow analysis (EW-MFA)**	Economy-wide material flow analysis (EW-MFA) is based on national economy-wide material flow accounts (EW-MFAcc) and balances that record all materials entering or leaving the boundary of the national economy. Data from these accounts, in particular those on material inputs, can easily be aggregated for communication purposes. They are usually reported by broad groups of materials and serve as a basis for deriving aggregated MF and RP indicators. Economy-wide accounts usually build on a fairly detailed data basis that, if well structured, can be used for many other purposes, including for in-depth analysis and for constructing indicators for specific materials or sub-groups of materials..

17 Moll and Femia, 2005.
18 NAMEA: National Accounting Matrix including Environmental Accounts.

Table 2. Material flow related analyses and associated issues of concern

Issues of concern	**Specific concerns related to environmental impacts, supply security, technology development**			**General environmental and economic concerns related to the throughput**		
	within certain businesses, economic activities, countries, regions			**of substances, materials, manufactured goods**		
	associated with			*at the level of*		
Objects of primary interest	**Substances**	**Materials**	**Products** (manufactured goods)	**Businesses**	**Economic activities**	**Countries, regions**
	chemical elements or compounds e.g. Cd, Cl, Pb, Zn, Hg, N, P, C, CO_2, CFC	raw materials and semi-finished goods e.g. energy carriers, metals (ferrous, non-ferrous), sand and gravel, timber, plastics	e.g. batteries, cars, computers	e.g. establishments, plants, small and medium sized enterprises, multi-national enterprises	e.g. mining, construction, chemical industry, iron and steel industry	e.g. aggregate mass of materials (& related materials mix), groups of materials, selected materials
Type of analysis	**Ia Substance Flow Analysis**	**Ib Material System Analysis**	**Ic Life Cycle Assessment**	**IIa Business level MF analysis**	**IIb Input-Output Analysis**	**IIc Economy-wide MF Analysis**
	⇳	⇳	⇳	⇳	⇳	⇳
Type of measurement tool	**Substance Flow Accounts ✪**	**Individual Material Flow Accounts ✪**	**Life Cycle Inventories**	**Business Material flow accounts**	**Physical Input-Output Tables ✪ ⦿, NAMEA-type approaches ⦿**	**Economy-wide Material Flow Accounts ✪**

✪: MFA tools using the materials balance principle. ⦿: MFA tools using national accounting principles fully in line with the SEEA.
Source: OECD, based on Bringezu and Moriguchi 2002.

Some of the measurement tools underlying MFA use accounting principles that are fully in line with the System of integrated Environmental and Economic Accounting (SEEA) and the System of National Accounts (SNA). This is the case of physical input-output tables and of NAMEA-type approaches. Other tools such as economy-wide material flow accounts, though very close to the SEEA accounting principles, present a few methodological differences. (Chapter 5).

All approaches and tools of the MFA family have their merits and drawbacks depending on the purposes for which they are to be used, and should be seen as complementary rather than exclusive tools. Their suitability and relevance for a given purpose depends on their specific information value and on a number of criteria, including their analytical soundness and measurability (technical feasibility, data availability and quality, cost of data compilation). The choice of the most appropriate tool has to take these criteria and related trade-offs into account. Experience shows that often the choice depends on the level of detail of the information required. The narrower the policy or management focus the more specific the information has to be.

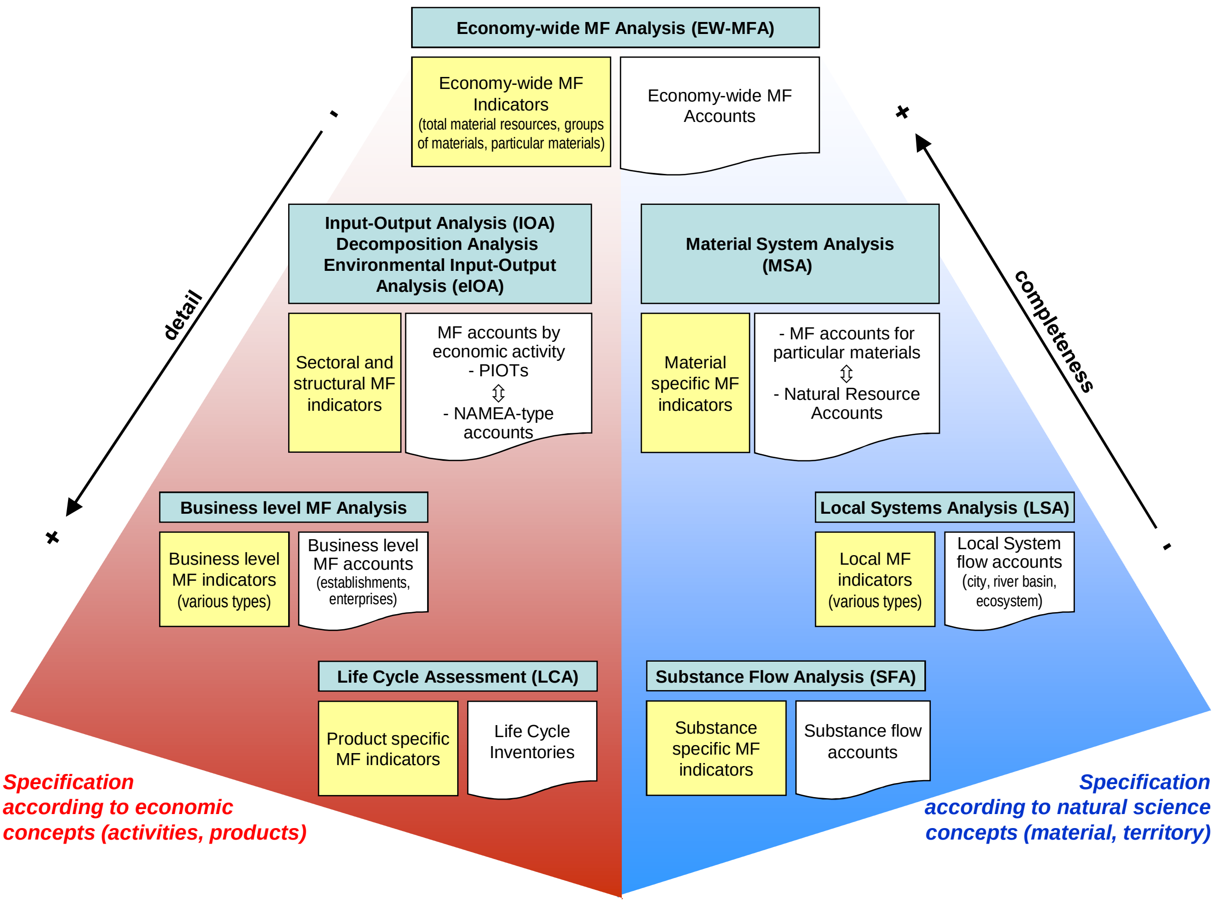
Important synergies exist between the different MFA tools and a rigid differentiation is not possible. Some of the tools overlap and their applications might be classified under more than one entry. Economy-wide MF accounts can for example be extended to include a breakdown by industry. The concepts used for economy-wide MFA are most commonly applied at the macro-level, but can equally be applied at business or local level. Physical input-output tables can be compiled for all material flows at any level of detail or for selected individual material flows; they can be compiled for a particular industrial sector or for the economy as a whole. Substance flow analysis is most commonly applied at the micro-level, but can equally be applied at the macro-level.

Often a combination of tools is necessary to gain the required insights. Input-output analysis can for example be combined with material system analysis or with life cycle analysis. Other promising combinations are those integrating physical and monetary analysis (hybrid approaches) and those associating MF data with other environmental or economic information and indicators.

Important synergies also exist with other information systems and analytical approaches, and MF information proves particularly useful when associated with these other tools.

A schematic overview of the different levels of detail and scale of application is given in Figure 3. It illustrates the relation between different aggregation levels, and between analytical approaches, the associated accounts and indicators derivable from the accounts. Emphasis can be put on (i) all materials entering and leaving the national economy; (ii) the industry level, enterprise level, and product level, from product groups down to specific products; (iii) certain material or substance flow systems, from the national down to the local level; or (iv) a combination of the different types of specifications. A description of some of the most common MFA tools and their applications at macro-, meso-, and micro-level is given in sections 3 to 5.

Figure 3 Architecture and level of application of MFA tools



When analysing material flows, emphasis can be put on:

❶ all materials entering and leaving the national economy (top of the Figure);

❷ the industry level, enterprise level, and product level, from product groups down to specific products (left hand side of Figure);

❸ certain material and substance flow systems, from the national down to the local level (right hand side of Figure); or

❹ a combination of the different types of specifications.

Source: OECD.

2.2. Links between MF information, other measurement tools and analytical approaches

MFA has many potential uses and users and can support a variety of public and private policies and actions (Chapter 2). They are however not the only tools available. Other tools exist and are used. To give the insights needed, the different MFA tools should therefore be positioned within a broader architecture of accounts, indicators and analytical tools, including economic modelling and qualitative assessments. This helps see the interrelationships between different types of information tools, and identify the most appropriate measurement tool and the most appropriate level of detail or aggregation for a given purpose, taking into account the resources and expertise available. It also helps inform users about the objectives, value-added and limits of the different MFA tools.

Important links are those that link MF accounts with other tools including (i) other environmental accounts and information, (ii) economic information, including national accounts and their aggregates, and productivity measures, (iii) modelling and forecasting tools, and (iv) analytical and evaluation tools, including decomposition analysis, and environmental input-output analysis. (Table 3).

Table 3 Links between MF information and other information tools

Environmental information	
Links with other environmental accounts and information are useful to enhance the relevance of MF information for environmental and natural resource policies and to relate MF indicators to environmental impacts. They are also important to populate MFAcc.	
Environmental accounts	Linking MF information with information derived from natural resource accounts (e.g. water, forest, land, energy) and from specific environmental accounts such as waste accounts is important to relate natural resource use and material flows to the stocks of natural resources available for use, and to give a comprehensive picture of the physical flows of materials.
Environmental information	Linking MF information with information describing specific environmental issues or derived from tools such as Pollutant Release and Transfer Registers (PRTR), air emission and greenhouse gas inventories, and waste statistics are important to enhance the policy-relevance and interpretability of MF indicators, to relate MF indicators to environmental pressures and impacts, and detect shifts in environmental pressures from materials use between environmental media (air, land, water), economic activity sectors or countries and world regions.
Economic information	
Links with economic information are important to enhance the relevance of MF information for economic and trade policies, and to enable the use of data from MFAcc in integrated economic and environmental models and analyses.	
Monetary input-output tables	National MFAcc in which inputs and/or outputs of the system are disaggregated by industry can be connected to monetary input-output tables to establish so called hybrid flow accounts in the context of integrated environmental and economic accounting. This helps attribute the use of materials and the associated generation of residuals to their ultimate economic purpose, i.e. the delivery of final products and services to consumers and investors, disaggregated by product groups or industries and by kind of final demand.
National economic accounts	Data from national MFAcc can be linked with data from national economic accounts and their aggregates without changing either type of account, assuming that both accounts are constructed using the same concepts and classifications. This helps calculate various types of resource efficiency indicators (intensity and productivity ratios, decoupling indicators).
Market prices, resource rents, etc.	Among other links that merit attention are those between trends in material flows (domestic, international) and trends in market prices of certain materials or groups of materials and trends in resource rents.

.../...

…/…

Forecasting tools

Links with modelling and forecasting tools are important to support longer term decision making and test the implications of different policy choices for resource productivity, supply security, technological and economic changes, and environmental quality.

Outlook studies and scenario development	MF information can be applied in outlook studies and scenario development to study future demands for materials and natural resources and related use and trade patterns. This provides a basis for informed policy development and implementation, including ex-ante and ex-post evaluation of policy performance. Sectoral MF indicators can be coupled with economic models distinguishing between different economic activity sectors in order to simulate business-as-usual or alternative developments[a]. LCI modelling, LCA and technology forecasting scenarios can be combined to estimate the to-be-expected environmental impacts of future technologies.
Econometric modelling	Aggregates from MFAcc and derived indicators can be used in econometric modelling, for example as elements of cost functions, or as endogenous variables in order e.g. to forecast future demand for strategic materials.
World economy models	Aggregates from MFAcc can be included in world economy models where they have a great potential for integrated analysis of the economic and environmental aspects of world-wide economic development and globalisation, of environmental burden-shifting phenomena or price implications of growing world demand.

Analytical and assessment tools

Links between MF accounts and analytical and assessment tools are crucial for successful material flow studies. This includes links with MFA related analyses and that are part of the broader MFA family of tools, as well as links with other analytical tools.

Value chain analysis	Material flow analysis of particular industrial materials, such as metals, can be combined with value chain analysis[b] (VCA) to shed further light on concepts such as resource productivity and their relation to labour productivity, raw material prices and competitiveness. This is a potentially very powerful way of analysing issues related to sustainable resource management, in particular at business level, but also at global level.
Input-output analysis and decomposition analysis	MF information from PIOTs can be applied in standard input-output analysis to calculate the total material requirement associated directly and indirectly to the final delivery of one unit of a given product (in terms of use of a certain material or generation of a certain residual) by ideally following the production chains backwards up to the system boundary. Provided the necessary monetary tables are available further analyses can be carried out: simulation of effects of changes in technology and/or in final demand composition and level, comparison between the situations of different national systems (decomposition or shift-share analysis), etc.
Environmental input-output analysis and life cycle assessments	Links with analytical tools such as environmental input-output analyses (eIOa) or the further steps of life cycle analyses, i.e. life cycle assessments (LCA) are important to relate material flows to environmental impacts and to detect shifts in environmental pressures from materials use between environmental media (air, land, water) or economic activity sectors. Environmental input-output analysis (or extended IOA) refers to the application of input-output techniques to the study of the relationships between the functioning of the socio-economic system and environmentally relevant variables, especially expressing the pressures exerted by production and consumption on the natural environment (material flows to and from the natural environment). The traditional input-output framework is extended for this purpose with the inclusion of the environmental variables, so as to allow their analysis
Other analyses	MF information can be associated with assessments of environmental and human health impacts of individual material flows. This helps synthesise information along common properties of different material flows. Specific analyses can be done on the trade dimension of material flows, making use of IO tables, to study the flows of resources physically and virtually embodied in traded products that take place between countries and parts of the world.

(a) Examples include the Panta Rhei model used to forecast the development of TMR of the German economy, Lutz, 2005, and the EU Mosus project.
(b) Value chain analysis (VCA) is a systematic approach to examining the activities that take place in a business and relating them to an analysis of the competitive advantages of the business. VCA has also become an increasingly useful approach to gain a comprehensive view of the various inter-locking stages involved from taking a good or service from the raw material to production and then to the consumer. See ILO, *Value chain analysis for policy makers and practitioners*, Geneva, 2005.

Source: OECD

Table 4. Characteristics of MF related accounts

Type of account	Characteristics	Economic activities		Materials		Flow types				Compilation effort
		Coverage	Level of detail	Coverage	Level of detail	Internal flows	Input flows	Output flows	Indirect & unused flows	
Economy-wide material flow accounts (EW-MFAcc) ✪	National macro-economic level. ⇩ Record all material flows at the system boundary. Report material flow data aggregated or by groups of materials	All activities	Low (macro)	Complete: all materials crossing the system boundary	Low in reporting. High in compilation	No (black box)	✓	✓	✓	low to medium
Physical supply-use and input-output tables (PIOTs) ✪ ⊙	National meso level ⇩ Record some or all materials broken down by economic branches, including intermediate exchanges.	All activities	Industry level (meso)	Usually complete, may be applied to selected materials	Low or by material groups, but may cover all levels	✓	✓	✓	✓	high
NAMEA-type tables for physical flows ⊙	National meso-level. ⇩ Record selected material flows disaggregated by economic branches, at the nature-economy boundary, or at some intermediate stage	All activities	Industry level (meso)	Selected goods (and services)	Low to very high	✓	✓	✓	No[a]	medium to high
Individual material flow accounts ✪	Meso level ⇩ Describe the life-cycle of selected industrial materials and their associated process system.	Activities related to the flows monitored	Industry level (meso)	Specific material	High (focus on a specific material)	✓	✓	✓	✓	medium to high
Physical flow parts of natural resource accounts (NRAcc) ⊙	Meso level ⇩ Describe the use of selected natural resources	Activities related to the flows monitored	Industry level (meso)	Specific natural resource	High (focus on a specific resource)	✓	✓	✓	No	medium to high
Life cycle inventories (LCI)	Micro level. ⇩ Describe the life cycle of products and their associated process system	Activities related to the flows monitored	Industry or plant level (meso-micro)	Environ-mentally relevant material flows related to a product	High	✓	✓	✓	✓[b]	high
Substance Flow Accounts (SFA) ✪	Micro level. ⇩ Describe the life cycle of a selected chemical substance and its associated process system	Activities related to the flows monitored	Industry or plant level (meso-micro)	Focus on a specific substance	Very high	✓	✓	✓	No	high

Notes: (a) NAMEAs do not cover indirect and unused flows under current practice, but could be extended to cover them. (b) Indirect and unused flows are conceptually included in LCI, but not always covered in practice.
✪: MFA tools using the materials balance principle. ⊙: MFA tools using national accounting principles totally in line with the SEEA.

Source: OECD.

3. MACRO-LEVEL MFA

When applied at the macro-economic level, MFA provides a comprehensive and systematic overview of the physical resource basis and requirements of all economic activities taking place within a national economy. It monitors the total amounts of materials, groups of materials or individual materials used in an economy (throughputs), usually considering both direct flows (i.e. flows of materials entering or leaving the economic process) and indirect and unused flows (i.e. flows of materials not entering the national economic process, but associated to upstream resource exploitation and materials processing and use).

Marco-level MF analysis is particularly useful to support decisions in areas such as economic, trade and environment policy integration, sustainable development strategies and action plans, and national waste management and resource conservation policies. It is less useful to support issue specific decision making that requires tools such as SFA, LCA or MSA.

3.1. Monitoring material flows at economy-wide level: Economy-wide material flow accounts and balances

Main measurement tools to support macro-level MFA are economy-wide MFAcc and balances tracking materials at various levels of aggregation and detail. These accounts are compiled in a physical accounting framework as described in the SEEA handbook and are largely compatible with the System of National Accounts[19] (SNA). In their simplest form, economy-wide MFAcc consider the economic system itself as a black box. The emphasis is on material exchanges between the economy and the environment − material inputs (imports, domestic extraction) and outputs (residuals, exports) −, and on material accumulations in national economies, less on flows within the economy. To address material flows within the economy, the accounts need to be expanded or complemented with PIOTs or NAMEA type accounts and related analyses (section 4.1).

Data from EW-MFAcc can easily be aggregated for communication purposes and can be used to monitor broad groups of materials (e.g. energy carriers, metals, construction minerals, timber, agricultural biomass) or total material flows. They are particularly useful for analysing overall long term trends and directions of the system under study and serve as a basis for deriving aggregated MF and RP indicators (Chapter 4). They give an overview of problems, opportunities and developments related to the use of certain types of materials, to the total material requirements and the physical growth of an economy or to the overall resource productivity of an economy. When grouped by material categories, they can be used to show the structure of an economy's resource basis, shifts between material groups and related substitution effects, and to describe the overall resilience of the national economy.

At a more detailed level, the data compiled to populate EW-MFAcc can, if well structured, be used to show shifts between individual materials at national level and related substitution effects. They can also be used to monitor input flows of selected resources or materials at national level for similar purposes as individual MFAcc (section 4.2).

When the subject of the analysis is a particular aspect of material flows, for example international trade flows, the analysis can be directly supported with international trade statistics expressed in physical terms, and does not necessarily require the construction of MF accounts.

[19] Differences remain as regards the treatment of semi-natural systems and the use of the residence principle. See *Measuring material flows and resource productivity: Volume II – The accounting framework* for details.

3.2. Implementing macro-level MFAcc

Economy-wide MFAcc are relatively easy to compile, in particular as regards direct national input flows of used material i.e. flows entering the economy. Direct flows are observable at the boundary of the economy. The statistical sources are well known and often readily available; compilation methods are relatively well developed and harmonised. Main data sources are mineral extraction statistics, production statistics for agriculture, forestry and fisheries, and foreign trade statistics. Regarding the output side, complete coverage is more difficult to attain due to less exhaustive information and to difficulties in estimating certain variables such as additions to stocks in physical terms. The statistical sources include data on products' dissipative uses*, waste statistics, water statistics, and air and GHG emission inventories.

*__Dissipative uses__ refer to the dispersion of materials into the environment as a deliberate, or unavoidable consequence of product use (e.g. fertilisers and manure spread on fields, or salt, sand and other thawing materials spread on roads).

When macro-level accounts are set up mainly for the purpose of indicator development, the level of detail and the compilation effort can be kept to a minimum. Experience however shows that when indicators derived from these accounts start to be used, this often creates a demand for additional data and analysis, which may lead to a subsequent expansion of the accounts in a multi-level and multi-dimensional way. The highest level of detail, feasible with available resources, should therefore be considered when establishing the databases and accounts underlying the indicators. This facilitates their stepwise expansion to include for example a breakdown by industry sector, or a better coverage of trade flows by country or region of origin or destination. (Chapter 5).

Examples include:

- Austria
- Belgium
- Czech Republic
- Finland
- France
- Germany
- Italy
- Japan
- Korea
- Slovak Republic
- Spain
- Switzerland
- United Kingdom
- United States (WRI project)

Comprehensive economy-wide MFAcc also require information on indirect flows and unused extraction. These are less easy to estimate robustly and raise a number of methodological questions. Indirect flows are not accounted for in the SEEA and need to be estimated by the use of modelling and inclusion of additional data. MF aggregates integrating indirect flows are therefore not fully compatible with national accounts aggregates. Also, economy-wide MFAcc are constructed according to the territory principle, as are energy statistics and balances and many environment statistics, whereas national accounts and the SEEA recommend the use of the residence principle. This should not be seen as a major obstacle, but may raise interpretation issues when the results are communicated in the form of indicators. It is therefore recommended to accompany economy-wide MFAcc with bridge tables.

4. MESO-LEVEL MFA

When applied at the meso level, MFA provides a more differentiated information tracking and analyses material flows at finer levels of detail within the economy, distinguishing not only categories of materials or individual materials but also industries or branches of production. This enables a more focused problem analysis, tailored to the respective material, industry or branch, which can be used to support material, industry- or branch-specific decision making and management.

Meso-level MF information is particularly useful to track structural changes at macro- and global level, to monitor developments in resource productivity and environmental performance at the meso level, and to support decision-making at these levels. It helps detect waste of materials, pollution sources and opportunities for efficiency gains in specific sectors, and serves as a basis for deriving related MF and RP indicators. It is most relevant for policies and decisions in areas such as integrated product

policies, energy and climate change policies (control of air and GHG emissions, energy efficiency measures), integrated waste management policies, sustainable materials management. It is equally relevant for policies and decisions concerning water management.

4.1. Monitoring material flows at industry level: Physical input-output tables, and NAMEA-type approaches

Main measurement tools to support meso-level MFA at industry level are physical input-output tables (PIOTs) and NAMEA-type tables[20]. Accounts following these approaches are compiled in a physical accounting framework in the form of physical supply and use tables (PSUs) as described in the SEEA handbook. They can easily be combined with monetary data in hybrid accounting matrices and are largely compatible with the System of National Accounts (SNA). They reflect the physical interrelations of an economy and provide a comprehensive description of material flows between the environment and the economy, as well as within the economy.

PIOTs account for some or all material transactions within a national economy, i.e. material flows broken down by economic branch and final demand category (at the same degree of detail as monetary national accounts), and all material transactions with nature (i.e. raw material inputs and waste/emission outputs). They can equally be applied to selected industries and to selected materials or material groups. PIOTs are mass balanced at the industry level.

By providing an interconnected picture of inter-industry flows, data from PIOTs and NAMEA-type tables can be used to analyse physical flows, considering the economic activities and structural changes that lie behind these flows, and to construct industry-specific waste or materials accounts based on the material balance principle. They can further be used to generate information on the indirect material flows of final demand and imports; to analyse the economic determinants of materials use and assess the effectiveness of policies targeting their reduction or substitution.

If compiled in a coherent framework, PIOTs and NAMEA-type tables can be used in combination with EW-MFAcc to facilitate analysis of material flows and to break down MF and RP indicators by sector or by industry. They can be used in decomposition analysis and as an input into modelling work. PIOT and NAMEA-type tables are also major data sources for carrying out Environmental or extended Input-Output Analyses (eIOA) that provide additional insights on the determinants of environmental pressures. Environmental IOA can cover indirect material requirements of imports, analogous to the TMR approach of EW-MFAcc.

When combined with monetary I-O analysis, physical input-output analysis and environmental input-output analysis are particularly relevant for supporting structural policies with environmental implications, such as taxes, subsidies, trading systems.

They can be related to monetary supply-use and input-output tables (MIOTs) through the establishment of hybrid flow accounts, including full NAMEAs, in order to highlight the relationship between economic and physical phenomena and analyse them jointly. Hybrid accounts can be used to study a wide range of issues. Essentially any raw material (or energy) input or waste material (or energy) output for which physical statistics are available can be analysed through hybrid flow accounts. Because issues of material resource use and waste output are pervasive across economies, hybrid flow accounts are among the most commonly implemented environmental accounts. This is of particular value for economic analysis, including work on productivity, value chains, technology diffusion, global warming, and structural changes.

[20] National Accounting Matrices including Environmental Accounts (NAMEA).

4.2. Monitoring particular materials: Individual material flow accounts and material system analysis

Main measurement tools to support meso-level MFA for particular materials are individual national MFAcc and certain natural resource accounts based on the materials balance principle. Data from such accounts are useful for analysing the magnitude of given material flows, their economic and environmental consequences, detecting supply problems, and pointing at unnecessary waste and emissions of the given material in the economy and at the related environmental burden and risks. They are further useful for analysing the magnitude of and shifts in particular material flows among countries and world regions, and the related environmental burden. Information from such accounts supports the management of particular industrial materials (e.g. timber, metals such as iron and steel, copper, aluminium; energy carriers, such as oil; plastics; construction materials such as sand or gravel) and enables issue-specific decision making analysis by focusing on materials of particular environmental and/or economic importance.

MFAcc for individual materials also help assess the scope for substitution between materials from recycled versus primary natural sources, identifying the factors that influence the recycling industry, the incentives and deterrents for recycling, and the existing niches for further use of recyclable materials and goods.

A material system analysis and derived indicators may, for instance, reveal potentials for recycling. When combined with LCA and derived impact indicators they can depict the environmental hot-spots of the processing network. They can also be used to model the effects of increased material efficiency and its implications for resource productivity and to monitor flows of materials throughout the supply chains.

Information to support MFA for particular materials can also be derived from certain parts of Natural Resource Accounts (NRAcc). NRAcc often have characteristics in common with individual industrial material flow accounts. This concerns in particular those NRAcc that describe the use in the economy of the materials derived from the natural resource under study and the flows of goods incorporating these materials by using physical supply-use and input-output tables for these goods (e.g. wood and wood products). In addition, NRAcc describe the stocks of resources and the stocks that are available for use, and can be used to compare the economic use of the natural resource with the available stocks. When scarcity or natural resource conservation is part of the concern, a combination of MF information with information from asset accounts is useful. Some NRAcc for renewable resources (e.g. water accounts) extend their analysis to the resource flows that take place inside the natural system and can be used to compare the human use of the resource with their natural reproduction rate.

4.3. Implementing meso-level MFAcc

The implementation of PIOTs is a labour-intensive task involving many data entries. It greatly benefits from the pre-existence of monetary input-output tables (MIOTs) and from the involvement of national accountants working on the construction of these tables. Given the data requirements, concrete experience with the analytical use of PIOTs is limited to a few countries and international projects, but is expanding. Often environmentally extended or hybrid input-output analysis (IOA) is used to attribute direct and indirect resource/material inputs and waste/emission output to industrial sectors based on the economic relations provided by monetary IO tables.

Examples include:
- Germany
- Japan (environmental IOA)
- Canada

NAMEA-type approaches address specific materials of particular relevance and are therefore less demanding as regards the materials covered, but need to be more precise. Moreover, NAMEA-like tables cannot be balanced at the industry level, and therefore cannot benefit from balancing and gap estimation techniques as much as PIOTs. They therefore require additional care in the construction of the accounting tables.

The implementation of an individual material flow account does not require high labour inputs, but may be limited by the availability of information on that material's internal flows in production and consumption. This is the case when the identification of the products and the wastes in which the material is or may be contained is not straightforward. For most natural resources and extracted industrial materials, the information basis is sufficient for implementing such accounts, though not at a high level of detail. Individual material flow accounts have been developed in many countries, often in the context of natural resource accounting and focusing on resources and materials of particular relevance to the country and its economy. In some cases, applications focus on particular stages of the material flow without describing the entire lifecycle of the resource (e.g. material flow databases derived from mineral statistics and geological surveys).

5. MICRO-LEVEL MFA

When applied at the micro level, MFA provides detailed information for specific decision processes at business (company, firm, plant) or local level (city, municipality, ecosystem, habitat, river basin) or concerning specific substances or individual products. It enables a focused problem analysis, tailored to the respective firm, plant or area, substance or product, that can be used to support firm-, area- and material-specific decision making and management, and monitor the alignment of economic and environmental performance at this level.

Business and local level MFA can track categories of materials or individual materials, as well as groups of substances or selected substances or study the material flows induced by an individual products' production and use. These MFA tools often overlap and are used in association with each other.

Micro-level MF information is most relevant for specific policies and decisions in areas such as health, chemicals, waste and materials management, and Integrated Pollution Prevention and Control policy (IPPC).

5.1. Monitoring material flows at business or local level

MF information from business-level MFAcc or mass balances is useful to monitor developments in resource productivity and environmental performance at the company or plant level. It supports the implementation of policies and decision in areas such as product policies, energy efficiency, integrated waste management, sustainable materials management, IPPC; it helps set corporate strategies on investments and emissions, and monitor the availability of critical resources and the vulnerability of a company or a plant to disruptions in the supply chain.

Company- or plant-level MFAcc can be relatively easy to compile depending on the purpose for which the information is to be used. Most of the time the basic data are readily available from internal business sources, the most important challenge being to ensure a minimum of coherence with meso and macro-level MFAcc.

Examples include:

- Europe: assessing MF in the context of Environmental Management Accounting (The EMAN Network) http://www.uni-lueneburg.de/eman/
- Switzerland: MF study carried out for the Canton of Geneva
- Alpine region: MFA to monitor sustainability
- Japan: MFA in the automobile industry (Toyota Motor corporation)
- Japan: MFA for local governments (Aichi Prefecture)
- United Kingdom: business level MFA as part of the Biffaward programme

Companies can easily use their financial and other management information systems to track the cost and input of raw materials, energy and labour, as well as the output of goods and services and waste products, in order to understand, and then to improve, their resource productivity and eco-efficiency.

Practical experience with detailed MFacc monitoring particular materials throughout the supply chain, has however shown some limitations at business level. This is associated with the complexity of the supply chains and the poor availability of certain data, particularly when tracking materials further downstream in the chain where they become embedded in goods and where the material contents for various categories of goods have to be assumed and calculated via modelling. Due to these limitations clear resource efficiency and productivity trends are hard to establish at business level for certain materials.

Box 3. Analysing material flows at territorial level: Examples

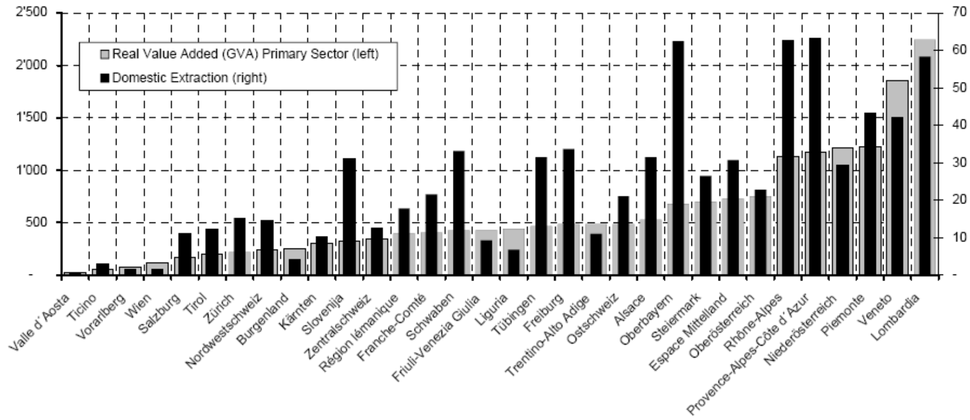
The Alpine region

In this example, indicators from material- and energy flow accounting were used together with other environmental, social, and economic indicators, to monitor the Alpine Region's sustainability (MARS project, 2005).

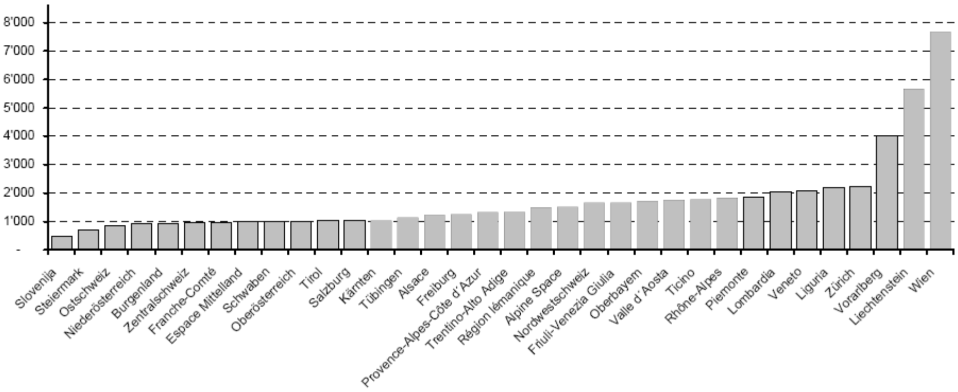
The project used the methodology for economy-wide MFAcc and adapted it to the territorial level. It provided information for calculating headline indicators including domestic extraction of materials, domestic material consumption and materials productivity, and the physical trade balance, but also disaggregated and detailed data for policy analysis.

The indicators were used for communication purposes, but also for providing an overview of the scale of the physical interaction between the economy and the environment, both in terms of materials and energy use.

Domestic extraction of materials and primary sector activities, 2000, million tonnes and million Euro



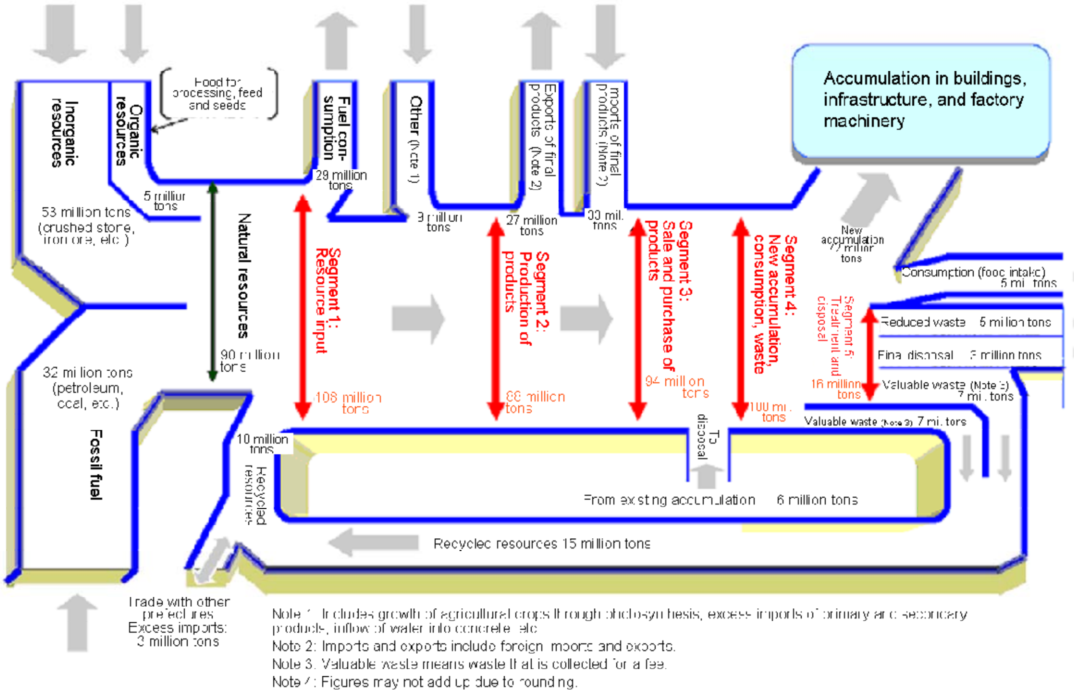
Materials productivity (GDP/DMC), 2000, Euro per tonne



Source: "Monitoring the Alpine Region's sustainability (MARS)" http://www.bakbasel.com/wEnglisch/benchmarking/interreg/mars_report_2005.shtml.

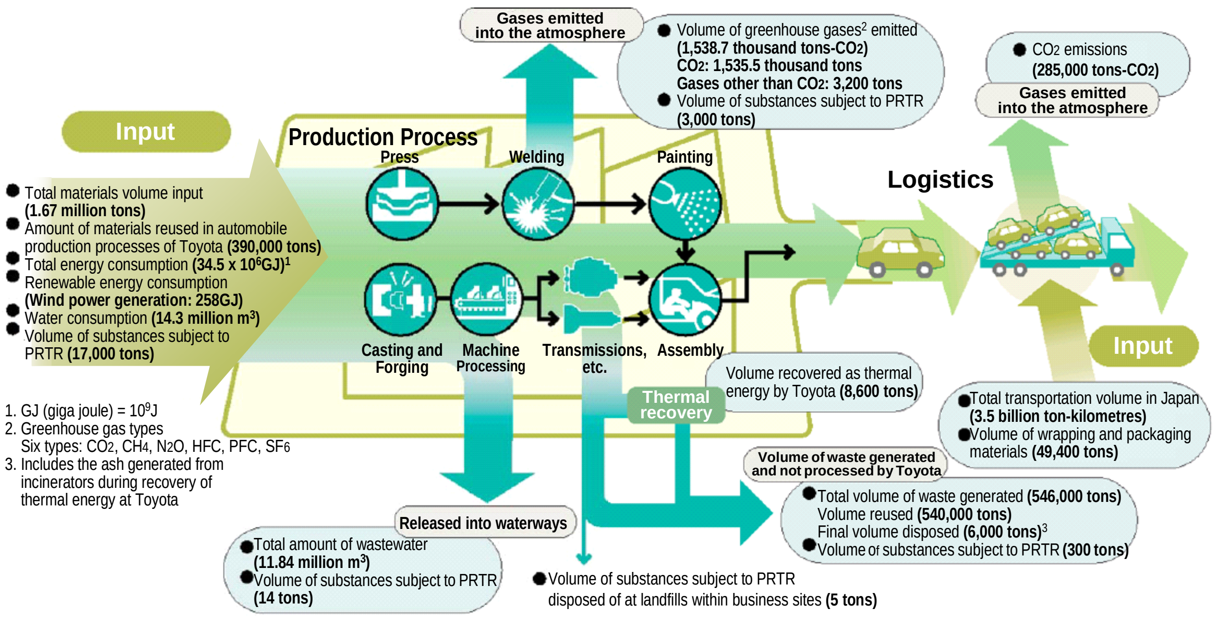
Box 4. Analysing material flows at local and business level: Examples

Material flows in Aichi Prefecture, Japan, 1999



Source: Aichi Prefecture, 2003

Material flows in corporate environmental reporting



Source: Toyota Motor Corporation, Environmental and Social Report, 2005

5.2. Monitoring selected substances: Substance flow accounts and analyses

Substance flow accounts and analyses (SFA) quantify the pathways of clearly defined chemical substances or compounds (e.g. chlorine, sulphur, mercury, nitrates) within a given system. SFA provides information that supports the management and control of substances that have already been identified to cause certain environmental problems or threats to human health, and that require further in-depth analysis to identify environmental 'hot spots' along the life cycle of a product or a specific substance. SFA can be applied at various levels (global, macro-, meso-, micro), but proves particularly useful at micro level. SFA usually focuses on those processes that release most of the substances studied to the environment. Assessing the criticality of these releases may be supported with information on substance specific impacts (e.g. eutrophication potential) or with information on substance specific critical thresholds.

MF information derived from SFAcc supports for example the implementation of policies related to the control of chemicals (e.g. control of hazardous substances, heavy metals, risk assessments) or to the control of specific pollutant emissions or discharges (e.g. control of air and GHG emissions). It helps design and refine related policy measures and helps identify those measures that solve the problem most effectively.

SFA can add value to pollutant release and transfer registers (PRTR) and help assess exposure to hazardous substances. It can also be associated with and add value to Life cycle analyses (LCA) that apply to products (see below).

The implementation of SFA is a labour-intensive task whatever the level of application is. A number of OECD countries have been carrying out work to study flows of specific substances or groups of substances (heavy metals, organic contaminants, nutrients, chlorinated hydrocarbons, dioxins, pharmaceuticals, hormones, etc.), often at the local level.

Examples include:

- Sweden: studies of metal flows in the Stockholm area; national substance flow cards for chemicals
- United States: study of substance flows in the New York/New Jersey harbour

5.3. Monitoring the material requirements of products: Life cycle inventories and assessments

The compilation of a Life Cycle Inventory (LCI) is a standard step in Life Cycle Assessment (LCA), which is a widespread decision-support tool in product related environmental policies. LCA allows the analysis of the problems related to a particular product and their origins, comparing improvement variants of a given product, designing new products and choosing between a number of comparable products. In the LCI phase all material and energy flows related to the life cycle of a product, which is the functional unit of the LCA, are systematically registered. The material inflows and outflows related to the given functional unit are aggregated by homogeneous materials, corresponding to specific environmental pressures[21]. Inflows and outflows however are not mass balanced for every process in the life cycle.

LCA can help answer all sorts of environmentally relevant questions related to a single product's life cycle. It helps identify all environmental pressures occurring along the life cycle (extraction, processing, use, recycling, disposal) of products and the most significant phase from an environmental point of view. It thus provides basic information for products management and control, highlighting the opportunities for reducing environmental pressures along a products' life chain. It can be used to encourage conservation, recycling and substitution of raw materials, including rare metals and environmentally harmful materials. Through additional information – e.g. on process technologies, costs, etc. – it helps identify the most effective intervention points. A common policy application of

21 This is done by using the results of Life Cycle Impact Assessments (LCIA). Impact categories considered include: climate change, acidification, eutrophication, summer smog, ozone depletion, eco-toxicity, radioactive emissions, resource depletion, land use.

LCA is the comparative analysis of the environmental performance of two or more similar products, e.g. for the assignment of eco-labels and prices.

LCA is the most comprehensive approach with regard to direct and indirect material flows and the resource requirements associated with products, considering these entities on a life-cycle-wide basis. The derivation of indicators was not the original purpose of this tool and related experience remains limited.

The implementation of LCA is a labour-intensive task. When the analysis focuses on the life-cycle wide material intensity of products and services, the task is usually less labour-intensive. The effort can then be limited to the input side and to establishing an inventory without further weighting. It is expected that in future the effort will also be reduced as more background data sets become available in LCI databases.

6. OVERVIEW OF INFORMATION VALUES AND POLICY APPLICATIONS OF MFA TOOLS

Different policies and different audiences have different information needs. Whether a given MFA tools is appropriate for a given purpose or policy use, depends among others on it specific information value. This value varies among the different MFA tools due to the different levels of coverage of the economy and of materials, and to the different levels of detail in the description of the flows.

Table 5 gives an overview of the types of questions that can be addressed when using data from MFAcc, directly or in connection with further analyses. These questions can be related to different policy issues. They also help define the indicators that are most appropriate to communicate the results from MFA to a broader audience. It has to be noted that many of these questions may be addressed by more than one MFA tool. Taken individually some of them may also be addressed by other information tools. The added value of MFA and related accounting tools is that they give insights into all questions of a set at once and in a coherent way.

Table 5. Purposes and uses of MFA-tools

Characteristics and level of application	Purpose and value-added	Limitations	Synergies with other tools	Examples of questions that can be addressed	Areas of use
Economy-wide material flow accounts (EW-MFAcc), other complete national MFAcc, and related analyses ✪					
National macro-economic level. ⇩ Record all material flows at the system boundary Report material flow data for aggregated total or by groups of materials Can also be applied at meso or micro level	Provide a comprehensive and systematic overview of the physical resource basis, the total material requirements and the resource efficiency of an economy Analyse related problems, opportunities and long term developments Provide a basis for aggregated MF and RP indicators Easy to compile	- no distinction between intermediate and final consumption - no distinction between regions of origin and destination of trade flows - no distinction between economic activities - does not cover internal waste flows and materials re-use, recycling and reduction	Can be combined with: - PIOTs or NAMEA-type tables - Trade statistics in physical terms - Waste and emission statistics - Physical asset accounts Can be used in: - modelling work Can be expanded to cover: - Major economic activities - Trade flows by region of origin and destination - Waste flows	- What is the **physical material basis** of an economy? What is the level and composition of the **domestic demand** for materials? - What is the material **productivity** of an economy and how does it relate to labour and capital productivity? - To what extent are material inputs into the economy **coupled** with economic output? with pollutant and waste generation? - How much of the materials required to sustain the economy can be **supplied from domestic sources**? What is their composition (materials mix, primary raw materials vs recycled materials, toxic vs inert materials)? - How **dependent** is the national economy on **external markets**? On imported materials? On demands from external markets? - What kind of products are **imported**, at which level of processing? what are their underlying material intensities? - Which materials leave the economy as **exports**? as **releases to the natural environment** (pollutants, waste)? - How much material **accumulates in the economy** in the form of stocks (buildings, infrastructure, durable goods, etc.)? - How much material is **removed** from nature to sustain the economy **without being used**? At home, abroad, worldwide?	- Economic and environment policy integration - Trade and supply security - Sustainable development strategies - National waste management and resource conservation policies - Communication and information policies
Physical supply-use and input- output tables (PIOTs), and related analyses, ✪ ⊙					
National meso level ⇩ Record some or all materials broken down by economic branches, including intermediate exchanges Can be applied to particular industries or businesses Can be applied at global level	Track structural changes at macro- and global level Monitor developments in resource productivity and environmental performance at industry level Detect waste of materials, pollution sources and opportunities for efficiency gains in specific sectors Analyse the economic determinants of materials use and assess the effectiveness of policies targeting their reduction or substitution Provide a basis for sectoral and structural MF and RP indicators	- Compilation effort is high - Incomplete coverage of indirect flows	Can be combined with: - EW-MFA - monetary I-O tables and analysis - value chain analysis - MSA - LCA - PRTRs Can be used in: - modelling work - decomposition analysis - environmental input-output analysis	- How much and which materials are processed by individual industries? How does this contribute to domestic **demand**? - Which industries **supply** these materials? - How **efficiently** are raw materials and intermediate products transformed into final products and residuals? How is resource **productivity** developing at the industry level? - Which share of the material inputs into the national economy reaches **final consumers** as products and which share is transformed into **residuals** during production ? - Which industries **deliver** these materials to consumers? How much is exported and by which industries? How much is **accumulated** in new stocks and which industries supply the durable products and investment goods in which matter is incorporated? - What are the **economic determinants** of material resource use? What **structural changes** underlie material flows in an economy?	- Economic policies - Economic and environment policy integration - Technology development and innovation - Industry policy - Sustainable production and manufacturing - Integrated waste management - Sustainable materials management - All structural policies with environmental implications

Characteristics and level of application	Purpose and value-added	Limitations	Synergies with other tools	Examples of questions that can be addressed	Areas of use
NAMEA-type tables for physical flows, and related analyses ☉					
National meso-level. ⇩ Record selected material flows disaggregated by economic activity sectors, at the nature-economy boundary, or at some intermediate stage	Partially overlap with those for PIOTs	- Compilation effort can be high - Does not cover all indirect and unused flows - Does not use the materials balance principle	Can be combined with: - EW-MFA - MSA - LCA - PRTRs Can be used in: - modelling work - decomposition analysis - environmental input-output analysis - hybrid input-output analysis Can be expanded to cover indirect and unused flows	- How **resource- and residual-intensive** are **industries and product** groups? What is the share of different industries in the generation of **residuals**? How important are these industries in economic terms? Which demands for final products influence the generation of residuals most? - How **resource- and residual- intensive** are domestic **consumption**, **investments** and **exports**? The use of which materials/products and the generation of which residuals is driven by final demand for given products? - Which industries **extract** natural resources? Which demands for final products influence this extraction most? - Which industries are **direct users of the extracted materials**? Which industries directly use **imported** materials? What are the shares of domestic and imported materials for these industries? - How does **economic growth**, technical progress and change in consumption, investment and export patterns (structural change) affect the use of materials and imported products and the generation of residuals? - How will **material use and residuals** develop under certain conditions? - What lies behind **cross-country differences** in the use of materials and imported products and in the generation of residuals?	- Economic policies - Economic and environment policy integration - Technology development and innovation - Industry policy - Sustainable production and manufacturing - Integrated waste management - Sustainable materials management
Individual material flow accounts and Materials System Analysis – MSA ✪					
Meso level ⇩ Describe the life-cycle of selected industrial materials and their associated process system.	Analyse the magnitude of given material flows, their economic and environmental consequences Detect supply problems Point at waste and emissions associated with the use of the given material in the economy and at the related environmental burden Reveal potentials for recycling	- methodology is not standardised	Can be combined with: - EW-MFA - LCA - Physical asset accounts - Value chain analysis Can be used in: - modelling work	- What is the level of the **demand** for a given material? - What is the **origin** of the material? How much is **produced domestically**? How much is **imported**? How do flows of a given material **shift among countries or world regions**? Are there risks of **supply** disruptions? - What are the **raw material requirements** for the full cycle of materials use? What are the inputs to its production? How much is further transformed? Into what? - How **efficiently** is the material used within the system? How much is used or **stocked** and where? How much becomes **waste**, how much is recycled, how much goes to final disposal? - Which share of the material is **released back to the environment**? Where does this release exert environmental pressures? Can the management system be improved and the pressures reduced? - What are the environmental implications of material **extraction**? - Where are critical '**intervention points**' in the materials' life cycle? Is there **scope for substitution** between materials (recycled versus natural)?	- Natural resource management (mineral systems, energy systems) - Sustainable materials management - Waste management - Resource conservation - Recycling markets - Trade and supply security - IPPC

Characteristics and level of application	Purpose and value-added	Limitations	Synergies with other tools	Examples of questions that can be addressed	Areas of use
Physical flow parts of Natural Resource Accounts (NRAcc), and related analyses ⊙					
Meso level ⇩ Describe the flows of selected natural resources and in some cases of derived products	Provide overview of natural resource use and flows Focused problem analysis, tailored to the respective natural resource that can be used to support natural resource management and conservation	- Gives a partial view of MF - Does not necessarily use the materials balance principle - Overlaps partially with MSA and detailed SU/IO tables	Can be combined with: - EW-MFA - NR physical asset accounts	- How much of a given resource has been used in a given period? What is the **natural growth** of a given (renewable) resource over a given period? What is its **rate of use** with respect to available stocks or proven reserves? - Which **industries** use the resource? - What **products** are obtained from the exploitation of the natural resource? - What **residuals** are generated in its transformation?	- Natural resource management (water, forest, fish, land) - Resource conservation - Sustainable materials management
Life cycle inventories (LCI) compiled in the framework of Life Cycle Assessments (LCA)					
Micro level. ⇩ Describe life cycle of products and their associated process system	Focused problem analysis, tailored to the respective product, that can be used to support material-specific decision making and management	- Does not use the materials balance principle	Can be combined with many other MFA tools	- Which **environmental pressures** occur along the life cycle (extraction, processing, use, disposal) of individual products? - Where can environmental pressures along a product's life cycle be **managed and controlled** best? - What are the life-cycle-wide environmental pressures of **product A** as compared to those of **product B**? - What is the **resource intensity** of a product? - Are there options for **substituting materials** that compose a product?	- Integrated product management and control - Product design; Green design - Eco labelling - IPPC - Government purchasing policies
Substance Flow Analysis (SFA) ✪					
Micro level. ⇩ Describe the life cycle of selected and very specific chemical substances and their associated process system	Focused problem analysis, tailored to the respective substance, that can be used to support material-specific decision making and management			- Where and how much of substance X is **flowing through** a given system? Where do flows of a substance X **end up**? How much of substance X is stored in **durable goods**? is flowing to **wastes**? - Where are potentials to use substance X **more efficiently** in technical processes? - Where are options for **substituting** the harmful substance? - Where do substances end up once they are **released** into the natural environment? - Where are the **environmental "hot spots"** of a substance along its life cycle?	- Chemicals control - Risk assessments - Environmental health - Specific IPPC - Hazardous waste management

✪: MFA tools using the materials balance principle. ⊙: MFA tools using national accounting principles totally in line with the SEEA.

Source: OECD, after Moll and Femia, 2005, and Bringezu, 2006.

Chapter 4. MEASURING PROGRESS: MATERIAL FLOW AND RESOURCE PRODUCTIVITY INDICATORS

Material flow indicators

are important tools for measuring progress with the environmental and economic performance of natural resource and material use.

- **Role and characteristics**
- **Desirable properties and selection criteria**
- **Types of MF indicators and main uses**
- **Guidance for use and interpretation**
- **Practical indicators for international use**

MEASURING PROGRESS
MATERIAL FLOW AND RESOURCE PRODUCTIVITY INDICATORS[22]

1. ROLE AND CHARACTERISTICS[23]

Material flow (MF) indicators are important tools for describing material resource use in the economy, and for informing about the economic efficiency and environmental effectiveness with which these materials are used in the production and consumption chain up to their final disposal. They inform about:

- The level and characteristics of the physical resource base of an economy or an activity.
- The environmental consequences of material resource use at national and international level.
- The effects of environment and economic policies on materials use, and the implications of trade and globalisation on national and international material flows.

As material flow and resource productivity issues have moved up the national and international policy agenda, MF indicators have gained importance in a number of countries. They are increasingly reported by national and supranational institutions and are often included in environmental or sustainable development indicator sets (OECD 2008c).

1.1. Terminology

1. The term "material flow indicators" has been commonly used to designate indicators derived from economy-wide material flow accounting that provide an overview of all material flows in a country. In this guide, the term "material flow indicators" is used in a broader sense: it designates all indicators that inform about the level and characteristics of material flows and material resource use, ranging from aggregated measures to measures of individual material flows, including substance flows. Such indicators can be derived from any of the MFA tools described in Chapter 3, as well as from other statistics.

> ***Definition***
>
> Material flow indicators are defined as quantitative measures, which point to, inform about, describe, the characteristics of material flows and material resource use and which have a meaning or a significance that goes beyond that directly associated with the underlying statistics.

1.2. Levels of application

MF indicators can highlight various aspects of the circulation of materials at different levels of specificity and aggregation. They can describe overall material flows to provide overview information at a glance; the can describe particular flows of individual materials or material groups. They can describe these flows at the local, national or international level; at the micro-, meso-, or macro-economic level.

In this document, emphasis is put on indicators that can be used by country governments to support the development and implementation of national policies and related international work. Focus is given

[22] This chapter builds on original documents prepared by Tomas Hak and Jan Kovanda, and by Stefan Bringezu.

[23] OECD (2003), OECD (1993).

to indicators actually used or promoted by intergovernmental organisations, government institutions at federal, national or state level, and research institutes. Such indicators are typically national in scope or reflect sub-national or sectoral issues of national significance.

Most of the indicators described here therefore relate to the national level, and can be derived from national MFAcc and from other national level statistics. Yet, the approach described may also be used to develop indicators at sub-national or at business level. The actual measurement of indicators at these levels is encouraged and lies within the responsibility of individual countries and businesses.

1.3. Functions, audiences and purposes

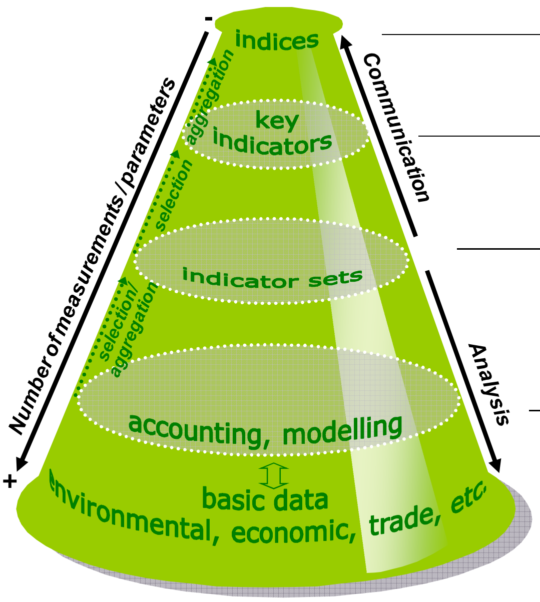
Functions

A key function of MF indicators is to simplify the communication process by which the results of MF analysis and accounting are provided to the users and to adapt the information provided to users' needs. Due to this simplification and adaptation, the indicators may not always meet strict scientific demands to demonstrate causal chains. They rather represent trade-offs between their relevance for users and policies, their statistical quality and their analytical soundness and scientific coherence. Indicators should therefore be regarded as an expression of the "best knowledge available" and need to be embedded in larger information systems (e.g. databases, accounts, monitoring systems, models). (Figure 4).

Audiences

Among the main audiences are the general public, journalists, managers and decision makers in the business and government sectors, policy-makers, including parliamentarians, and stakeholders from NGOs. Most of these audiences are non-experts. It is therefore crucial that the indicators are communicated in a way that is understandable and meaningful, and that reduces the complexity and level of detail of the original data.

Figure 4. Information pyramid



Role	Audience	Properties
Raise awareness	General public, Journalists, High-level policy makers & managers, Parliamentarians	Aggregated and/or weighted index
Support information & communication		Small set of indicators (max.10)
Support decision making & policy coherence	Government officials, Managers, Stakeholders, Policy analysts	Larger sets of indicators (≅30-40)
Support analysis & in-depth studies	Policy analysts, Researchers, Statisticians	Detailed and/or comprehensive statistical basis; Multi-purpose

Material flow indicators are a digested sub-set of a more complex whole in the information hierarchy. Their role is to inform about key properties of the system under scrutiny by making use of selected data, i.e. those that are most relevant for a given use or policy field.

Material flow accounts and databases give a detailed and comprehensive picture at the bottom of the information pyramid. Their role is to provide a sound and reliable data basis from which indicators can be derived and that enables in-depth studies and analyses.

Source: OECD.

General purposes

MF indicators serve many purposes depending on the level at which they are applied, on the specification of the material flows being studied, and on the quality of the underlying data sets.

- They support public communication by giving the public, the media, stakeholders and high-level decision makers an overview of major issues and trends concerning the use of material resources and the associated environmental and economic implications.
- They support decision making by informing policy makers and managers about results achieved and progress to be made, and by pointing at developments that require further analysis and possible action.
- They help promote policy integration and coherence by informing policy makers and managers about the interrelationships between different aspects of materials use and management.

Specific purposes

MF indicators are particularly useful to measure progress with the environmental and economic performance of natural resource and material use at macro-economic level and at the various stages of the production and consumption chain.

- They help measure performance with respect to the efficiency or productivity of material use. They can be used to monitor material use intensities and related changes over time (decoupling trends). They can be used to encourage more efficient resource use and promote re-use of what is currently discarded and unnecessarily wasted.
- They help measure performance with respect to the effectiveness with which MF related policies and measures are implemented[24]. They can be used to set and monitor MF related policy goals and quantitative targets, such as those included in national sustainable development strategies or in national waste management plans. Data quality permitting, they can further be used for benchmarking and comparison purposes over time and across countries.
- They similarly help measure the economic and environmental performance of industries, monitor trade related environmental issues, and capture critical aspects of the materials supply of national economies.

Environmental indicators and performance evaluation

Using **indicators in performance evaluation** implies putting these indicators in the context of national and international objectives, and linking them to the measurement and analysis of achievements, and to underlying drivers and countries' specific conditions. One distinguishes:

◆ Performance indicators **linked to quantitative objectives** (targets, commitments) such as air or GHG emission trends related to national or international targets;

◆ Performance indicators **linked to qualitative objectives** (aims, goals) that address performance in two ways:

First, with respect to the *eco-efficiency of human activities,* linked to the notions of de-coupling, elasticities. Examples include emissions per unit of GDP, relative trends of waste generation and GDP growth, resource productivity.

Second, with respect to the *sustainability of natural resource use*. Examples include the intensity of use of freshwater resources (abstractions related to the available renewable resource stock).

Performance indicators are often used in conjunction with **descriptive indicators**, i.e. indicators not linked to explicit objectives, but describing major conditions and trends.

Source: OECD, 1993, 2003.

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24 Eco-efficiency programmes; resource productivity measures; sustainable materials management; waste prevention measures; integrated product policies; management of hazardous materials and substances, and control of their transboundary flows; integrated pollution prevention and control, etc.

Main issues and questions

MF indicators generally help address the following issues and questions:

> ❶ **What are the material requirements of an activity or an economy?**
> Which and how much material resources are used for what purposes? How much is non-renewable vs. renewable, primary raw material vs. secondary raw material? How does this change over time? How does this relate to available stocks of natural resources?
>
> ❷ **To what extent is an activity or an economy dependent on external material inputs or on external material markets?**
> How much stems from own vs. foreign territory (resilience, dependence, supply security)? How does this change over time? To what extent do international material flows shift between countries and world regions? How does this relate to foreign outsourcing, international trade and market prices for materials?
>
> ❸ **How efficiently are material resources being used?**
> Are valuable resources wasted unnecessarily? What is the level of coupling or decoupling of economic growth, resource use and environmental pressures? How does this relate to the productivity of the economy, of industrial sectors?
>
> ❹ **Which potentials for improvement in resource productivity exist?**
> Which opportunities arise from improved materials management and resource policy? How does this relate to labour and capital productivity?
>
> ❺ **What are the main environmental risks and impacts associated with material resource use?**
> Where are these risks located in the material cycle (extraction, processing, transport, consumption, disposal) and how do they change over time?
>
> ❻ **What are the main environmental consequences associated with international material flows?**
> How do these consequences change over time and shift between countries and world regions?

The answers to these questions are of relevance to decisions in many policy areas, ranging from economy, trade and technology development, to natural resource management and environment policies (e.g. pollution prevention and control, chemicals management, waste and materials management) (Chapter 2).

MF indicators address these questions at the general level by giving an overview of major issues and trends and by attracting attention to developments that require further analysis. Answering these questions usually requires the use of more than one indicator. What is needed is a set of indicators that collectively give the necessary insights and balance the messages conveyed by particular indicators. These indicators have to be carefully selected, using well defined and agreed upon criteria (section 2.4).

1.4. Data sources and calculation methods

1.4.1 Data sources

There are several statistical sources that can be used for calculating MF indicators. Among these are:

- The measurement tools of the MFA family including physical supply-use and input-output tables, NAMEA-type accounts, substance flow analysis and accounts, individual material flow accounts, economy-wide material flow accounts and balances.[25].

[25] see also Bringezu (2000), Femia, A. and Moll S., (2005).

- Physical flow accounts for natural resources – renewable and non-renewable resources (e.g. forest, water, minerals, energy), and related asset accounts.
- Other data sources such as foreign trade statistics, industrial production statistics, waste statistics, emission inventories, pollutant release and transfer registers (PRTR), etc. Data from these sources are usually needed to populate MF accounts, but are also useful when used directly to calculate certain indicators.

The suitability of each of these data sources depends on the purpose for which the derived indicators are to be used and on the level at which they are to be applied. The narrower the policy or management focus the more specific the information has to be, and the more detailed the underlying accounts and databases have to be. Often a combination of several sources is necessary to calculate the indicators.

Generic indicators

The most common national MF indicators in use can be derived from simple economy-wide MFAcc considering only flows of materials entering the economy (input flows), without the need to compile a complete material balance. They usually represent medium to top-level aggregates of the accounting variables, with top-level aggregates covering all materials, except water and air.

Most OECD countries that have developed a national set of environmental or sustainable development indicators include in their set one or several indicators derived from simple national EW-MFAcc. These indicators are best suited for supporting broader policy considerations. They often serve general information and communication purposes, and contribute to raising awareness. They are less suited for supporting policy analysis, unless complemented with more detailed statistics (e.g. on MF by economic activity) or broken down into their constituent variables, by material groups (e.g. metals, construction minerals, fossil fuels, woody and other biomass) or by flow type (e.g. used and unused material flows, primary and secondary raw materials).

Issue-specific indicators

Similar, but more specific indicators reflecting particular problems can be derived from more sophisticated MFA tools such as material system analysis (MSA), substance flow accounts and analysis (SFA), life cycle assessments (LCA) and extended input-output analysis (eIOA) or from comprehensive national MFAcc. A higher level of detail can be reached with regard to:

- economic activities, industries, enterprises, product groups (meso level) down to life-cycle-inventories and analyses of specific products;
- specific materials and substances and the analysis of related flows;
- a combination of these two types of breakdowns,

in line with Figure 3, page 46.

Practical experience with indicators derived from comprehensive MFA tools remains limited, and their calculation is often more data intensive. The experience gained so far as part of research projects and at company level could serve as a basis for developing further guidance.

Specific indicators can also be derived from other statistics such as international trade statistics to reflect changes in international flows of materials, their origin and their destination, and to inform debates about international trade in certain materials, including recyclable materials and remanufactured goods.

1.4.2 Measurement units and calculation methods

Physical units and absolute values

MF indicators are usually reported in physical mass units (such as metric tonnes). When presented in absolute terms they are most relevant when monitoring trends over time or when related to targets referring to absolute values. They can describe one particular aspect of the life cycle of materials such as material inputs, outputs or consumption, or reflect the materials balance by combining two aspects of the materials life cycle to construct so-called balance indicators. Such basic indicators can be directly derived from the main variables of MFAcc (section 3).

Ratios and intensities

Many MF Indicators are expressed in relative terms as ratios (e.g. intensities, % shares, trend indices). They can be calculated by relating material flow variables to environmental variables or to socio-economic variables (e.g. GDP, population size) to construct pollution intensity ratios, decoupling indicators, and productivity ratios, or to data on management approaches to construct so called consistency indicators. The construction of intensity and productivity ratios is facilitated by the existence of an underlying accounting framework similar to that used for national accounts. The choice of the numerator and the denominator is important, as is the statistical coherence between the two.

Aggregation

MF indicators often present aggregate material flows. They can be calculated in different ways.

- One approach sticks to grouping materials by common characteristics using their mass as the unit of the measurement. This can be done by using standard material groups such as construction minerals, metals, or biomass, or by using material groups that are tailored to the users' needs such as toxic materials, bulk materials, secondary raw materials or recyclable materials. This simple aggregation method is used for most indicators included in existing sets of environmental or sustainable development indicators. It generally works well for low to medium levels of aggregation, but may raise interpretation issues for higher levels of aggregation.

- Other methods consist in weighing the materials according to given criteria.

  One example is the weighing of material inputs according to their potential environmental impacts by using LCA impact factors that are derived from the impact assessment methodologies used in LCA[26]. Environmentally weighted MF indicators are expressed in equivalent reference units. Such indicators have been receiving increasing interest as tools that help monitoring the environmental outcomes of material related policy measures. But practical experience remains limited, and there are still problems of data availability and of weighing methods that constrain a systematic development of such indicators at the international level. (section 5.5.2).

  Another example is the weighing according to the exergy embodied in the materials. Exergy is a thermodynamic state variable measuring the useful part of the energy, i.e. the part that is available for performing work[27]. Exergy weighted indicators are expressed in equivalent energy units. Experience with such indicators is limited to research projects.

[26] van der Voet et al. 2005; de Bruyn.

[27] According to the first law of thermodynamics, energy can change form or quality, but can never be created or destroyed. Energy and mass are in principle inter-convertible ($E=mc^2$). When a fuel burns, both the mass and the energy content of the fuel (and the air) are exactly the same as the mass and energy content of the waste products. What has changed is the availability of the energy in the fuel for doing work. This availability is quantifiable, and is denoted "exergy". (Wall 1977, Ayres et al. 2004).

2. DEVELOPING MATERIAL FLOW INDICATORS

In practice, there is no unique or universal set of indicators that could be recommended. Whether a given indicator or set of indicators is appropriate depends on the purpose for which it is to be used, the target audience and the level of application. This needs to be taken into account when selecting and defining material flow indicators, and when choosing the most appropriate data sources. One also needs to consider the synergies that exist when different types of MF indicators are used in parallel and when MF indicators are paired with other indicators (natural resource indicators, waste or pollution indicators; economic and trade indicators, technology and innovation indicators).

When developing MF indicators it is thus important that the purpose and level of ambition of the effort are defined at an early stage, that the work is structured in a way useful to both the producers and the users of the indicators, and that the indicators are selected according to well accepted criteria.

2.1. Defining the purpose and the level of ambition of the indicator effort

The issues to be considered when developing MF indicators include the following:

- What is expected to be achieved with the indicators? Are they to be used as tools for public communication, for decision making, for performance evaluation? Are there any particular problems that are to be addressed?
- What is the audience, who are the main users? What are their information needs? What is their level of expertise?
- What are the pros and cons of different indicators? Are new indicators needed? Could similar messages be obtained by using already existing indicators as proxies? Or by combining simple MF indicators with other indicators to gain further insights?
- Are the data needed to calculate the indicators available or can they easily be made available? Are these data of sufficient quality and well documented? Are they updated at regular intervals? If new data have to be generated or compiled, what are the costs and benefits involved? How much additional data work (collection, estimation, new surveys, accounts) will be required? How long will it take to see first results?

The proposed indicators can be characterised according to the availability of the underlying data (short term, medium term or long term availability). This helps preparing the further development of the indicators, while delivering first results at an early stage by using proxy indicators.

2.2. Structuring elements

When developing a set of MF indicators it is important to structure the work in a way useful to both the producers and the users of the information, and to ensure that nothing important has been overlooked. This can be done in various ways, using different frameworks and structuring elements.

Frameworks and types of indicators

One way is to distinguish between different types of indicators. This is commonly done by arranging the indicators in an accounting framework with reference to the materials balance scheme and to the underlying accounting variables and identities. This allows to distinguish between three generic types of indicators: input, consumption, balance and output indicators. (section 3). The indicators can also be arranged by grouping them according to elements in the process chains or the commercial life-cycle, or by classing them according to their calculation methods and associated reference values (performance indicators, descriptive indicators).

When MF indicators are to be used for environmental reporting purposes or for economic-environmental policy integration, they need to be associated with other indicators (environmental, economic) to set up a balanced set. In this case the indicators can be usefully arranged within the Pressure-State-Response (PSR) framework. This allows to distinguish between pressure, state and response indicators, where:

- Pressure indicators reflect the environmental pressures (direct and indirect) originating from material flows and materials use. Most MF indicators described in this report belong to this category.
- State indicators reflect the state and changes in environmental conditions that can be attributed to material flows and materials use. MF indicators are not suited for describing changes in environmental conditions. Such indicators have to be derived from other data sources than MFA.
- Response indicators reflect the extent to which society responds to these changes. Such indicators describe individual and collective actions and reactions, intended to mitigate, adapt to or prevent human-induced negative effects on the environment; halt or reverse environmental damage already inflicted; preserve and conserve nature and natural resources.

The **PSR framework** helps see environmental and economic issues as interconnected. It is based on a concept of causality: human activities exert pressures on the environment and change its quality and the quantity of natural resources (the "state"). Society responds to these changes through environmental, general economic and sectoral policies (the "societal response"). The latter form a feedback loop to pressures through human activities. In a wider sense, these steps form part of an environmental (policy) cycle which includes problem perception, policy formulation, monitoring and policy evaluation.

Issues of concern and categories of use

A second way is to distinguish between the purposes and uses for which the indicators are to be designed for. This is commonly done by arranging the indicators by issue of concern and by type of question to be addressed. This helps avoid choosing indicators only on the basis of data availability or of accounting identities and is more meaningful to users. It also helps define the appropriate level of detail and the type of material resource(s) to be covered. Relevant indicators for each issue or category of use can be selected from all types of indicators (input, output, and consumption indicators, pressure, state, and response indicators).

In this document five categories of use building on the questions listed in section 1.3 are presented.

❶ **Monitoring the material basis of national economies and industries.**
This requires indicators that reflect the level and characteristics of materials use in the economy or in industries (and process chains).

❷ **Monitoring the material productivity of national economies and industries.**
This requires indicators that reflect the intensity of materials use in the economy or in industries (and process chains), and that can be linked to productivity issues and eco-efficiency measures.

❸ **Monitoring the interactions of trade and globalisation with material flows.**
This requires indicators that reflect international movements and trade in materials (raw materials, semi-finished goods, materials embodied in finished goods, recyclable materials, hazardous materials) and that can be linked to issues of foreign outsourcing, demand and supply issues, and environmental risks and safety issues.

❹ **Monitoring the management of selected natural resources and materials.**
This requires indicators that reflect developments in selected materials that raise concerns as to the environmental consequences of their production and use, the adequacy of their supply, or the effectiveness of their management. Such indicators can be linked to issues of natural resource management, biodiversity, waste and materials management, as well as to specific resource productivity issues.

❺ **Monitoring the environmental impacts of materials use (overall and specific).**
This requires indicators that reflect developments in materials that raise concerns as to the environmental consequences of their production and use. Such indicators can be linked to issues of toxic contamination, environmental health, biodiversity, waste management, but also to natural resource management.

2.3. Desirable properties

Since the indicators can serve different purposes, their selection should as much as possible build on criteria that characterise the desirable properties of the indicators, are commonly agreed upon, and can be used to validate the indicators' choice.

Simplicity and ease of understanding

To fulfil their role as information and decision making tools, the indicators need first to be simple and easy to understand. Their number should be kept to a reasonable minimum so as to avoid cluttering the overview they are meant to provide.

The indicators should be "directionally safe" with regard to the issues they address or, when used for performance evaluation, with regard to the objectives or reference values associated with them. They should be embedded in a solid data basis that is readily accessible or can be made available at a reasonable cost/benefit ratio. These data should be of known quality and be updated at regular intervals in accordance with reliable procedures. The indicators further need to be founded on sound scientific grounds or theoretical frameworks.

For use in international work, the indicators should, in addition, be based on variables that are additive across countries, so as to enable the calculation of regional totals, and benefit from an international consensus as to their validity.

Acceptance and credibility

Indicators play an important role in stimulating and informing debates centred around the messages they convey. These messages need to be credible for the stakeholders involved and debates that question the validity of the indicators instead of focusing on the messages conveyed must be avoided. It is therefore crucial that the indicators are broadly accepted and legitimate in the eyes of users[28], that they benefit from a consensus about their validity, and that the process put in place to select and define the indicators involves the different stakeholders and users at an early stage. This in turn depends on the institutional credibility of the indicator provider[29].

Acceptance and credibility are crucial to promote wider use of the indicators by policy makers, policy analysts and decision makers in the business sector and to gain feedback on the indicators' usefulness and limits. This helps refine the indicators' definitions and improve the quality of the underlying data and accounts.

2.4. Selection and validation criteria

The properties described above are summarised in three basic selection and validation criteria:

- policy relevance and utility for the users;
- analytical soundness, and
- measurability of underlying data.

These criteria are commonly used for environmental indicators[30] and are in line with the quality criteria used for statistical activities[31]. They can easily be specified further so as to address those issues that are of particular importance for MF indicators. (Table 6).

28 Parris and Kates, 2003.
29 The credibility of an indicator or an indicator set refers to the confidence that users place in them based on their image of the indicator provider. One important aspect is trust in the objectivity of the data. Credibility is determined in part by the integrity of the production process. This can be influenced by institutional factors such as the institutional structure of a country, the level of co-operation between institutions, the administrative culture, and other factors.
30 OECD (1993, 2003), Moldan and Billharz, 1997, Sing et al., 2002.
31 OECD (2004), Quality Framework for OECD Statistical Activities, www.oecd.org/statistics/qualityframework

The extent, to which these criteria are met by the different indicators, helps identify their advantages and added value, as well as their limits and drawbacks. It has to be noted that in practice no indicator fully satisfies all the selection criteria. There are always trade-offs between the analytical soundness and robustness of the measurement tools chosen, the practicality of their implementation and their particular relevance in countries or in international work. It is therefore important to choose indicators that are as appropriate as possible to the purpose, while maintaining full awareness about their limitations.

2.4.1 Policy relevance and utility for the users

Policy relevance means the degree to which the indicators serve the purpose for which they have been designed for. Utility for the users means the degree to which the indicators are adapted to the users' needs. These criteria encompass interrelated aspects concerning the interpretability of the indicators and their significance vis-à-vis the issues to be addressed.

The interpretability of an indicator reflects the ease, with which the user may understand and properly use the indicator. The ease of interpretation in turn depends on many factors, including its ability to give a representative picture of the issue to be addressed, i.e. material flows and their interactions with the environment and the economy. It is affected by methodological and measurement issues, such as the internal coherence of the indicator's constituent variables and the level of aggregation of the indicator. The interpretability of indicators that reflect the overall use of material resources in an economy by aggregating all material flows in a given category may for example be hampered by the dominance of large material flows or by "over-expectations" as regards their significance. (section 3.5).

The significance or meaning of an indicator can be either specific, i.e. for a given issue, or generic, i.e. in a broader context. MF indicators are expected to be of significance for environmental issues and for economic and trade related issues, and to be responsive to developments in resource productivity, in the environment, and in the underlying drivers. When the indicators are to monitor particular materials or groups of materials, the selection of the materials to be covered should consider:

- the environmental significance of the materials, i.e. their significance with respect to pollution issues, to natural resource management and to waste and materials management issues.
- the economic importance of the materials, i.e. their significance with respect to economic growth and supply security, international trade and technology development.

For indicators used in international work, the policy relevance also encompasses aspects concerning their international comparability, and their ability to be adapted by countries to suit specific national or sub-national circumstances.

2.4.2 Analytical soundness

Analytical soundness means the degree to which an indicator is theoretically well founded in technical and scientific terms, is based on international standards and international consensus about its validity, and lends itself to being linked to economic and environmental models, forecasting and information systems.

For MF indicators, this encompasses aspects related to the internal coherence of the indicators, their external coherence with national accounts aggregates and with other productivity measures, and their additivity across countries.

Coherence

The internal coherence of an indicator reflects the degree to which its constituent variables are logically connected and mutually consistent. It means that all material or flow categories that are

covered by a particular indicator should be counted in a mutually consistent and statistically coherent way.

The external coherence with national accounts aggregates reflects the degree to which the constituent variables of an indicator can be connected to economic indicators or data in a coherent way. This criterion is important for indicators that reflect intensities or productivity ratios and that are to be used to monitor material efficiency or decoupling trends. It implies that the data underlying the indicators are based on common concepts, definitions and classifications, and that any differences are explained and can be justified. It is thus useful to compare the way efficiency indicators are constructed with the way GDP is defined, and to choose the appropriate nominator and denominator when defining such indicators. The coherence with productivity measures such as labour or capital productivity or multi-factor productivity is important to enhance the relevance of material productivity measures for economic policies and to relate them to competitiveness issues.

Additivity across countries

This criterion is important for national level indicators that are to be used in international work and for which regional aggregates are to be calculated. It has a bearing on the policy relevance of the indicators and is related to methodological issues. Not all MF variables are additive across countries. This may lead to double-counting and could require adjustments to be made (section 4.3.3).

2.4.3 Measurability

The measurability of the data necessary to calculate the indicators is often a key factor in the development of indicators. It encompasses aspects related to the availability and quality of the data, and to the data production process. The data should be readily accessible or made available at a reasonable cost/benefit ratio; the should be adequately documented and of known quality; and be updated at regular intervals in accordance with reliable procedures.

Two interrelated aspects are important for all MF indicators: data accessibility and data accuracy. Accuracy means the degree to which the data correctly estimate or describe the quantities or characteristics they are designed to measure. It refers to the closeness between the values provided and the (unknown) true values. The desirable level of accuracy of the data composing MF indicators varies depending on the indicator's purpose and its level of aggregation. When the purpose is communication, the level of accuracy should be sufficient to address an order of magnitude and to allow valid coherence over time and between countries. When the purpose is policy formulation and analysis, the level of accuracy needs to be higher.

Certain MF variables, such as unused flows, are measured indirectly. This raises the question of the completeness of the estimates and of statistical uncertainties that may hamper the significance of the resulting indicators. It also raises the question of the accessibility of the underlying data.

Table 6. Selection criteria for Material flow indicators [a,b]

POLICY RELEVANCE AND UTILITY FOR USERS	
A MF indicator should: ♦ Provide a representative picture of material flows and their interactions with the environment and the economy; ♦ Be simple, easy to interpret and able to show trends over time; ♦ Be responsive to changes in economic activities, resource productivity, technology development and the environment; ♦ Have a threshold or reference value against which to compare it, so that users can assess the significance of the values associated with it; ♦ Provide a basis for international comparisons; ♦ Be either national in scope or applicable to sub-national issues of national significance. ♦ Lend itself to being adapted to specific national and sub-national circumstances.	Particular aspects to be considered: ♦ The environmental and economic significance of MF indicators: – the relation to environmental pressures or impacts – the relation to economic and trade related issues ♦ The choice of appropriate reference values to which MF indicators can be compared ♦ The level of aggregation/detail of MF indicators. – Sets of indicators that collectively give the necessary insights versus a highly aggregated indicators. ♦ The country-specific factors that have a bearing on the significance of MF indicators
ANALYTICAL SOUNDNESS	
A MF indicator should: ♦ Be theoretically well founded in technical and scientific terms; ♦ Be based on international standards and international consensus about its validity; ♦ Lend itself to being linked to economic and environmental models, forecasting and information systems.	Particular aspects to be considered: ♦ The internal coherence of MF indicators ♦ The external coherence of MF indicators: – with national accounts aggregates; – with productivity measures such as capital productivity, labour productivity, multi-factor productivity; ♦ The additivity of MF variables to enable the calculation of regional aggregates (for the OECD as a whole or for OECD regions, for the European Union, for the G8, for world regions).
MEASURABILITY	
The data required to support the indicator should be: ♦ Readily accessible or made available at a reasonable cost/benefit ratio; ♦ Adequately documented and of known quality; ♦ Updated at regular intervals in accordance with reliable procedures.	Particular aspects to be considered: ♦ The level of ambition pursued and the choice of the data sources to be used. ♦ Data accuracy (completeness and statistical uncertainties) due to the indirect measurement of certain MF variables. This is especially important for certain aggregated EW-MF indicators and their interpretation.

a) Based on OECD (1993).
b) These criteria describe the "ideal" indicator; not all of them will be met in practice.
Source: OECD.

3. MAIN TYPES OF MF INDICATORS AND THEIR RELATION TO THE MATERIALS BALANCE[32]

MF indicators generally correspond to the main variables of MF accounts and describe the use of materials in the economy at the different stages of the flow chain, from resource extraction to final waste disposal. In line with the materials balance scheme the main types of indicators are: input indicators, consumption and balance indicators, and output indicators. These different types of indicators convey complementary information. They can be combined with each other to give a balanced picture of the issue described. They can be combined with economic indicators to construct efficiency ratios.

All MF accounting variables can in principle be used as indicators as long as their significance extends beyond that of their constituent statistics. In practice, not all of them are meaningful as indicators.

Since MF indicators came into existence and attained the recent shape, some have gained more attention than others. The sections below describe the different indicators that can be derived from economy-wide material flow accounting and subsequent analysis, with a focus on those that are the most commonly used. These indicators can be calculated for aggregate economy-wide material flows[33] or for particular materials, products or substances, depending on the purpose for which they are developed. See also the glossary of terms at the end of this document.

3.1. Input indicators

Input indicators describe the materials mobilised or used for sustaining economic activities, including the production of export goods and services. They are closely related to the mode of production of a particular country or region. They are sensitive to changes in the level and patterns of foreign trade and to other factors such as a country's endowment in natural resources, and its level of technology development and uptake.

The most commonly used indicators are: Domestic Extraction Used (DEU), Direct Material Input (DMI) and Total Material Requirement (TMR), as well as Imports (IMP).

Domestic extraction used (DEU)	DEU measures the flows of materials that originate from the environment and that physically enter the economic system for further processing or direct consumption (they are "used" by the economy). They are converted into or incorporated in products in one way or the other, and are usually of economic value.
Direct Material Input (DMI)	DMI measures the direct input of materials for use into the economy, i.e. all materials which are of economic value and are used in production and consumption activities (including the production of export goods and services); DMI equals domestic extraction used plus imports.
Total Material Requirement (TMR)	TMR includes, in addition to DMI, the unused flows associated with the extraction of materials that do not enter the economy as products and the (indirect) material flows that are associated to imports but that take place in other countries. It measures the total 'material base' of an economy. Adding unused and indirect flows converts imports into their 'primary resource extraction equivalent'.

Other measures of material inputs that can be derived from MFAcc include: Raw Material Equivalents of Imports (RME_{IMP}); Raw Material Input (RMI); Total Material Input (TMI), Unused Domestic Extraction (UDE); Total Unused Extraction (TUE); Indirect Flows Associated to Imports (IF_{IMP}); Domestic Total Material Requirement (domestic TMR).

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32 This section builds on *Economy-wide material flow accounts and derived indicators – A methodological guide,* Eurostat, 2001 and on OECD workshops on material flows and resource productivity (Helsinki 2004, Berlin 2005, Rome 2006).

33 They can be derived from a set of accounting modules, as described in section 5.3.

3.2. Consumption indicators

Consumption indicators describe the materials consumed by economic activities. They are closely related to the mode of consumption and are rather stable over time. The difference between consumption and input indicators is an indication of the degree of integration of an economy with the global economy, that also depends on the size of the economy.

The most commonly used consumption indicators are: Domestic Material Consumption (DMC) and Total Material Consumption (TMC):

Domestic Material Consumption (DMC)	DMC measures the total amount of material directly used in an economy (i.e. excluding indirect flows). DMC is defined in the same way as other key physical indictors such as gross inland energy consumption. DMC equals DMI minus exports.
Total Material Consumption (TMC)	TMC measures the total material use associated with domestic production and consumption activities, including indirect flows imported (see TMR) less exports and associated indirect flows of exports. TMC equals TMR minus exports and their indirect flows.

Other consumption indicators include: Raw Material Consumption (RMC).

3.3. Balance indicators

Balance indicators describe the physical growth of materials within the economy. Either as net flows of materials added to the economy's stock each year taking into account gross additions and removals from the stocks. Or as net flows of materials coming from the international trade (physical trade flows). Balance indicators usefully supplement consumption indicators.

The most commonly used indicators are: Net Additions to Stock (NAS); Physical Trade Balance (PTB):

Net Additions to Stock (NAS)	NAS reflect the physical growth of the economy, i.e. the net expansion of the stock of materials in buildings, infrastructures and durable goods. In MFAcc, NAS may be calculated indirectly as the balancing item between the annual flow of materials that enter the economy (DMI), minus exports (EXP), minus materials that return to the environment as residuals after use in the economy (domestic processed output: DPO), taking into account the appropriate items for balancing. NAS may also be calculated directly as gross additions to material stocks, minus removals (such as construction and demolition wastes and disposed durable goods, excluding materials recycled).
Physical Trade Balance (PTB)	The PTB reflects the physical trade surplus or deficit of an economy. It is defined as imports minus exports (excluding or including their hidden flows).

3.4. Output indicators

Output indicators describe the material outflows related to production and consumption activities of a given country. They account for those materials that have been used in the economy and are subsequently leaving it either in the form of emissions and waste, or in the form of exports.

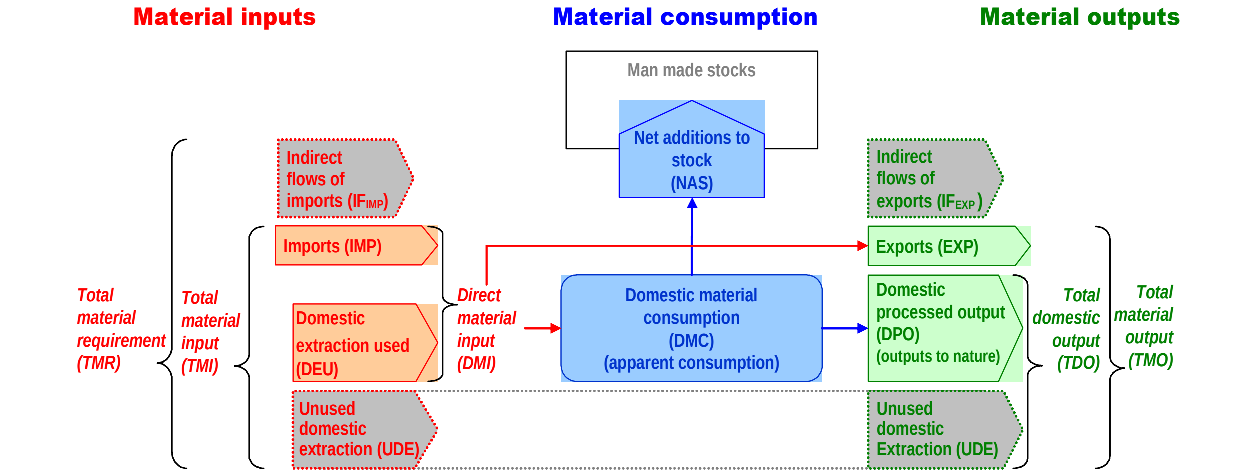
The most commonly used output indicators are: Domestic Processed Output (DPO), Total Domestic Output (TDO), as well as Exports (EXP).

Domestic Processed Output (DPO)	DPO measures the total weight of materials extracted from the domestic environment or imported, which after use in the economy flow back to the environment. These flows occur at the processing, manufacturing, use, and final disposal stages of the production-consumption chain. Included are emissions to air, industrial and household wastes deposited in landfills, material loads in wastewater and materials dispersed into the environment as a result of product use (dissipative flows).[34]
Total Domestic Output (TDO)	TDO represents the total quantity of material outputs to the environment caused by economic activity. TDO equals DPO plus unused domestic extraction.

34 The way in which oxygen contained in certain output flows is accounted for affects the resulting values (e.g. CO_2 or H_2O).

Other measures of material outputs that can be derived from MFAcc include: Raw Material Equivalents of Exports (RME_{EXP}); Indirect Flows Associated to Exports (IF_{EXP}); Emissions and Wastes (EW); Dissipative Use of Products (DUP). Direct Material Output (DMO), Total Material Output (TMO).

Figure 5. Main groups of MF indicators and their relation to the materials balance



Direct material input
DMI = DEU + IMP

Total material input
TMI = DMI + UDE

Total material requirement
TMR = DMI + UDE + IF_{IMP}

Domestic material consumption (DMC)
DMC = DMI – EXP
= DEU + PTB = DEU + IMP – EXP

Total material consumption* (TMC)
TMC = TMR - EXP – IF_{EXP}
= DMC + UDE + IF_{IMP} - IF_{EXP}
= DEU + UDE + IMP + IF_{IMP} - EXP - IF_{EXP}

<u>BALANCE VARIABLES</u>

Net additions to stock (NAS)
NAS = DMC - DPO

Physical trade balance* (PTB)
PTB = IMP - EXP

Domestic processed output
DPO = DMC - NAS

Total domestic output
TDO = DPO + UDE

Total material output
TMO = DPO + UDE + EXP
= TDO + EXP

* not represented graphically above.

Source: OECD, based on *Eurostat* (2001)

3.5. Efficiency indicators

<u>Efficiency indicators</u> are constructed by relating economic output indicators (such as GDP or value added) to economy-wide or sectoral MF indicators, thus providing information about the <u>material productivity or intensity</u> of the economy or economic activity sectors. GDP per DMI, for example, indicates the direct materials productivity, whereas the GDP per TDO measures the economic performance in relation to the material losses to the environment. (section 5.2)

3.6. Other indicators

Material flow variables can also be related to data on management approaches to provide information on the degree to which anthropogenic MF are embedded in natural systems in a sustainable way that allows continued use (e.g. share of renewables in DMI stemming from sustainable cultivation schemes). Such "consistency" indicators[35] are under development. They require additional information on management aspects not available from MF accounts and related statistics. Consistency indicators have similarities with indicators reflecting the intensity of use of natural resources by relating harvested or extracted amounts to sustainable yield levels or the annual growth of the resource.

[35] The term "consistency indicators" was introduced by Bringezu (2004) to respond to demands not only to reduce material flows through efficiency but also enhance "consistency" between economy and nature through a higher share of resources "fitted" to the natural regeneration capacities; the term "consistency" was promoted e.g. by Huber, J. (2004); the share of biomass to indicate natural regeneration capacity may be misleading since biomass is often overused (e.g. overfishing, soil degradation); thus information on proper stewardship for natural resource management is required e.g. by existing certificate labels (e.g. FSC).

4. AGGREGATED MF INDICATORS: STRENGHTS AND LIMITS

Each of the indicator described above has its own strengths and limits for different purposes. To gain a better understanding of what these strengths and limits are, it is useful to review the indicators against some of the selection criteria described above, focussing is on those that influence the interpretation and the significance of the indicators most. This includes:

- **Policy relevance and utility for the users** :
  Level of aggregation and aggregation methods; relation to environmental pressures and impacts
- **Analytical soundness**:
  Internal coherence; external coherence with national account aggregates; additivity across countries
- **Measurability**:
  Data accuracy and accessibility

4.1. Level of aggregation and aggregation methods

MF analysis and complete national MF accounts result in the recording of many different materials. As a consequence, communicating the results of such studies in the form of indicators requires a minimum of aggregation. A major objective of economy-wide material flow accounts for example is to enable the aggregation of different material flows into simple national level MF indicators that serve communication purposes and inform about progress towards broad policy goals. Over the past years there has been increasing interest in such indicators. At a high level of aggregation, these indicators however entail a risk of oversimplification, and reservations have been voiced as to the limitations of their use.

Aggregation is "the process of adding variables or units with similar properties to come up with a single number that represents the approximate overall value of its individual components"

(UNDESA, 2000).

4.1.1 Main strengths

For certain purposes, aggregated measures of material flows are useful. This is the case for example when measuring the overall physical size or material requirements of an economy or an activity, when establishing a relation between economic indicators and indicators for materials use (e.g. to reflect the overall material productivity of an economy), or when using MF indicators to inform about progress towards broad policy goals or targets.

Among other strengths of aggregated measures of material flows is their potential to simplify the public communication process and to reach audiences that usually receive little information of this type. This is useful for policy makers and the public at large who need well-synthesised information without getting lost in detail.

From a methodological and statistical point of view, the strengths of aggregated indicators derived from MF accounts include the following:

- They are organised in an already-familiar and rational framework with distinct and clear relations among the indicators, based on the underlying accounting identities and the materials balance principle.
- They are rooted in underlying accounts that record materials on lower aggregation levels.
- The underlying accounts record all materials in a common mass unit, tonnes or volume units that can be converted to mass units. This enables data aggregation in a common metric without the need to go through further data transformations and conversions. The computation of the indicators only involves simple additions and deductions.

- Aggregated MF indicators do not involve subjective judgements about the choice of the materials to be covered. All material flows within a certain flow category (i.e. domestic extraction used, domestic unused extraction, imports, exports etc.) or within a certain material groups are, by definition, counted in (except water as a resource).

In theory, these factors have the potential to lead to high methodological soundness. In practice, there are however a number of open questions that require attention and that affect the interpretability of the indicators. Some of them are common to all aggregated MF indicators, others are more indicator-specific.

4.1.2 Main limits

The prevailing reservations as to the limits of aggregated MF indicators are summarised as follows:

- Quantities of particular materials can vary considerably from year to year, as do monetary values, while the aggregated figure may remain constant. Highly aggregated indicators can therefore hide important variations in their constituent variables. Their value can be dominated by one single material group that masks developments in other material groups. In the absence of an appropriate documentation or breakdown of the indicators, this may hamper interpretability.

  For example, the question whether construction minerals such as sand, gravel and stones should be summed up with the other material groups or not has to be carefully considered in accordance with the purpose for which the indicators are to be used. Usually, such materials are included in aggregated EW-MF indicators, but their important weight raises questions as to how interpret the resulting aggregate[36]. Revealing the materials mix or sectoral breakdown behind an aggregated MF indicator helps overcome this weakness. As a general rule, all materials that are aggregated should at least share one common property that is key to the message conveyed by the resulting indicator[37].

- Aggregated MF indicators may involve some implicit judgement about the choice of the materials covered because of the assumption that every movement or transfer of materials or energy from the natural environment to another place has the potential to alter the environmental balance. This assumption is broadly accepted, but is seen by some users as debatable.
- The availability of basic data needed to populate the underlying accounts may affect the "completeness" of some of the indicators, and hence their information value. Not all variables are easily captured, notably those reflecting unused and indirect flows.

Many problems of interpretation or abuse arise when aggregated input or consumption indicators are used to reflect the environmental impacts of material resource use. Aggregate weight measures indicate mass turnover per time and do not consider other characteristics of materials than weight. The actual environmental pressure of material flows and the subsequent impacts on environmental conditions however depend on the chemical and physical properties of the materials and on the way the materials are managed across their life-cycle.

4.2. Relation to environmental pressures and impacts

Indicators derived from MF accounts typically describe environmental pressures and can be related to economic drivers. Their main value therefore lies with their capacity to provide insights into

36 Water for example is generally not summed up with other material groups because of its properties and its associated environmental concerns that differ from those of other materials, and because of the mass turnover of water that would overwhelm that of all other material groups.

37 For instance, construction minerals could be aggregated with other materials representing (used) primary extraction to give an indication of those environmental pressures arising from resource extraction and subsequent processes that are independent from the material properties (e.g. pressures on landscapes) and to monitor the mass turnover of specific future potential waste streams (e.g. construction and demolition waste).

quantitative resource issues, to detect major trends in resource use that are of environmental significance and to point at developments that can have potential negative impacts on the environment. They can however not be used to establish a direct cause-effect relationship between resource exploitation and use, actual environmental impacts and subsequent changes in environmental conditions. This requires indicators based on specific monitoring and analysis, and focusing on particular materials or substances.

In practice, indicators of environmental pressures often act as proxies for monitoring potential environmental impacts without establishing a direct cause-effect relationship. Aggregated EW-MF indicators have for example been used as proxies for the generic environmental pressure associated with the use of material resources. Depending on the way the indicator is calculated, the type of pressure covered and its location differ. The indicators can reflect the pressure exerted on the domestic environment or on other countries' environment (the rest of world environment); they can also reflect a mix of pressures on the domestic and the foreign environments. Aggregate domestic material consumption (DMC) can for example be used as a proxy for the potential pressure related to domestically consumed materials, while aggregate total material consumption (TMC) would in addition reflect the pressure associated with the unused material flows and upstream flows of foreign trade.

It has to be noted that the most common material input and consumption indicators in use, such as direct material inputs (DMI) and DMC, give only partial insights into the environmental pressure associated with materials use. This is because they account only for the amounts of materials actually used in the economy, and not for the amounts of hidden flows of materials, i.e. raw materials extracted abroad to deliver the imports and materials that do not enter the economy as priced goods but that are of environmental significance. Indicators such as total material requirements (TMR) or total material consumption (TMC) that account for all types of flows, including hidden flows, are considered to give a more representative picture of the potential environmental pressure.

In general it is recommended to characterise the indicators in a way that reveals constituent variables that are most meaningful for environmental purposes, or to work with a set of indicators to gain the necessary insights.

4.3. Analytical soundness

4.3.1 Internal coherence

The most commonly used MF indicators such as DMI and DMC record material inputs partly in the form of raw materials (extracted and imported raw materials) and partly in the form of products (imported semi-finished and manufactured products). When MF indicators are disaggregated by material groups or focus on selected materials groups, this lack of internal coherence can lead to negative values for some material groups when certain flows, such as exports, are subtracted. Negative values are not easy to understand and more difficult to interpret.

Expressing MF input and consumption indicators in raw material equivalents helps overcome this difficulty. Indicators such as raw material inputs (RMI) and raw material consumption (RMC) record all material inputs in the form of raw materials, and are hence more consistent internally and easier to interpret. The values of such indicators cannot be negative due to the laws of thermodynamics. Their calculation requires however more work to estimate the raw material equivalents of products and to develop appropriate conversion factors.

4.3.2 External coherence with national account aggregates

Consumption indicators are the closest equivalents to national accounts aggregates such as GDP, NDP or gross capital formation. Domestic Material Consumption (DMC) and Total Material Consumption (TMC) are therefore well suited for calculating overall intensities or productivity measures in which the

numerator and denominator have to be consistent and for comparing developments in material consumption with developments in GDP over the same period (section 5.2).

Input indicators such as DMI, TMI or TMR are less coherent with national accounts aggregates, and hence less well suited for calculating certain productivity measures. Since input indicators include imports, but not exports, imports can also be added to the numerator to ensure coherence, e.g. (GDP+IMP)/TMR[38].

In practice, full coherence with national accounts aggregates may not be needed for all indicators. Coherence is particularly important when calculating productivity ratios. In other cases, exceptions to that rule may be appropriate depending on the purpose for which the indicators are to be used. For example when national account aggregates such as GDP are used as a denominator to normalise MF indicators as is commonly done for certain environmental indicators (total emissions of sulphur oxides per unit of GDP) or energy indicators (total primary energy supply per unit of GDP).

Box 5 National account aggregates and material flow variables

GDP can be defined in several ways: as the sum of gross value added (output minus intermediate consumption), as the sum of final uses (i.e. excluding intermediate consumption and imports);as the sum of primary income distributed by resident units.

In the economy, as materials are processed, and goods and services produced, value added is generated along the production chain. The monetary unit value of materials generally increases when transformed from raw materials to semi-manufactured to final products. After final use, the value of materials tends to become very small (recyclable waste and scrap) or negative (waste and emissions). At the same time, the amount of useful material gets reduced along the production and consumption chain due to losses (wastes, emissions) at each transformation stage. In general, as value is added, material is 'used up' and the material content of products is reduced. Also, the standard circular model of the economy shows that money and physical goods (or labour) flow in opposite directions in economic transactions (hence, e.g. physical exports of products correspond to 'imports' of money).

The **closest parallel to material flow accounting** can be established for the calculation of GDP as the sum of final uses. The textbook formula for this is:

GDP = C+I+X-M, where: C = final consumption of households and government,
I = investment (gross capital formation),
X = exports, and M = imports.

Imports are deducted in this formula whereas for material input indicators imports are added, and for material consumption indicators, such as DMC and TMC, exports are deducted. This is because physical and monetary flows have opposite directions.

However, the physical economy does not always strictly parallel the monetary transactions in the economy as described in the national accounts. For example:

- consumer durables are treated as final consumption in the national accounts - adding final consumption expenditure on consumer durables to the gross capital formation is an option to make the physical and monetary figures more comparable (see e.g. Stahmer et al 2000);
- gross capital formation includes non-physical items (such as software) so that the result of any comparison would be the average physical intensity of capital formation, influenced by structural changes in the composition of capital formation;
- there is no direct correspondence between the consumption of fixed capital (depreciation) and the physical discard of capital goods (see e.g. Smith 1995).

Source: Eurostat, 2001 (page 38, 4.12-4.17).

4.3.3 Additivity across countries

Some of the most common economy-wide MF indicators are not additive across countries, i.e. adding them up across countries leads to double-counting. This is the case of input indicators such as DMI or TMR, which comprise imports, but not exports. It also the case of certain output indicators such as DMO or TMO, which comprise exports, but not imports. This "inadditivity" may be perceived as a shortcoming, but should not be seen as an obstacle. To avoid double counting, regional totals (e.g.

38 For details see e.g. Moll et al (1999) and Femia et al (1999).

OECD total, EU total) for such indicators can be calculated after intra-regional foreign trade flows have been netted out.

4.4. Data accessibility and accuracy

Certain MF variables are measured indirectly. The data needed are rarely acquired by statistical surveys or direct measurements and must be calculated or even estimated to populate the accounts. This is the case of variables related to domestic unused extraction, raw material equivalents and indirect flows associated with foreign trade. It may also be the case for some output variables, such as emissions to water or landfilled waste.

Data accessibility for these variables is rather low. The accuracy and the uncertainties related to them and to the derived indicators have however not been reviewed in detail. The largest uncertainties are expected for indicators such as raw material inputs (RMI), raw material consumption (RMC), total material requirement (TMR), total material consumption (TMC) and for net additions to stock (NAS) when calculated indirectly.

4.5. Guidance for use

Many of the limits described above can be overcome by (i) not attaching more meaning to the indicators than they actually provide; (ii) informing the users about value and limits, and (iii) augmenting the indicators with other indicators to gain a more balanced picture.

The collection and presentation of MF data should therefore always be carried out at a level which disaggregates economic sectors, material groups and types of flows. It is further essential that the aggregated indicators are accompanied with contextual information that describes the national circumstances (environmental, economic, social) of the countries and related developments over time. This is especially important when the indicators are to be used in international work, but also when they are to be used in countries to guide decisions related to resource productivity and sustainable resource use.

If highly aggregated MF indicators are to be used, they should as appropriate:

- be **augmented with other indicators** to gain a more balanced picture
- be presented with a **breakdown** by major material groups
- be related to **reference values**
- be accompanied with **contextual information** about the characteristics of national economies and underlying drivers.

Using a small set of key or headline indicators generally presents a good alternative; it provides a more transparent and comprehensive picture than a single aggregated measure. Ten up to fifteen key indicators may be a small enough number to be accepted among government policy makers, the question remains whether such a number will really capture the newspaper headlines next to the main economic indicators. A number of around three indicators is seen as appropriate to attract media attention.

Table 7. Overall strengths and limits of aggregated MF indicators

Strengths	Limits
Analytical soundness and measurement aspects	**Analytical soundness and measurement aspects**
♦ Easy to understand because expressed in familiar metrics (tonnes) ♦ Based on generally accepted framework ♦ Rooted in accounts that record materials at a lower level aggregation ♦ Theoretically sound ♦ Computationally simple, little subjective judgements about materials to be covered	♦ Sensitive to weaknesses in constituent variables including data gaps (e.g. hidden flows, or certain materials) ♦ Conflicting movements in constituent variables may mask important underlying trends (e.g. movement in flows of bulk materials versus movements in flows of toxic materials) ♦ Aggregated weight may mask important underlying characteristics (e.g. usefulness and relative value of commodities such as gold or salt or arsenic, differ vastly).
Usefulness and relevance	**Usefulness and relevance**
♦ Useful as tools for raising awareness and monitoring progress towards broad policy goals or targets ♦ Attract attention to broad trends that deserve further analysis ♦ Good proxies for overall resource use and the scale of potential environmental pressure ♦ Useful for capturing the newspaper headlines next to the main economic indicators	♦ Assumption that every movement of materials has the potential to alter the environmental balance seen as debatable by some users ♦ Not appropriate for monitoring environmental impacts ♦ Not appropriate for supporting issue specific decision making

Guidance for use

- Present together with information on constituent variables (materials mix, flow types)
- Document with additional information on the characteristics of national economies
- Relate to reference values as appropriate
- Position in broader set of indicators

Source: OECD.

Table 8 Selected advantages and drawbacks of aggregated EW-MF indicators

	Measurability		Analytical soundness			Relation to environmental pressure		
	Data accessibility & accuracy	Breakdown by material groups	Internal coherence when broken down by material groups	Additivity across countries	Coherence with SNA	Relation to overall pressure	Location of pressure reflected	Type of pressure reflected
DMI	+	+	-	no	0	-	domestic + ROW	mixed
TMI	0	+	-	no	0	0	domestic + ROW	mixed
RMI	-	+	+	no	0	0	domestic + ROW	mixed
TMR	-	+	0	no	0	+	domestic + ROW	mixed
Domestic TMR	0	+	0	yes	-	0	domestic	+/- generic
DMC	+	-	-	yes	0	-	domestic + ROW	mixed
RMC	-	-	+	yes	+	0	domestic + ROW	+/- generic
TMC	-	-	0	yes	+	+	domestic + ROW	+/- generic
NAS	-	-	-	yes	..	-	domestic	+/- generic
PTB	+	-	-	yes	0	-	ROW	mixed
DPO	0	+	-	yes	..	-	domestic + ROW	specific
TDO	-	+	-	yes	..	0	domestic + ROW	mixed
DMO	0	+	-	no	..	0	domestic + ROW	specific
TMO	-	+	-	no	..	+	domestic + ROW	mixed

Note: + high/good, 0 average, - low/bad, .. needs further review, ROW - rest of the world
Source: OECD.

Box 6. Quality criteria for aggregated environmental indices

In response to the increasing interest in and reservations on aggregated environmental indices, the OECD has reviewed the most common aggregated indices used in its member countries, and has identified their strengths and weaknesses for decision making and public information.

Aggregation has been defined as "the process of adding variables or units with similar properties to come up with a single number that represents the approximate overall value of its individual components" (UNDESA, 2000). It typically requires a series of steps, that usually involve more or less subjective choices and judgements.

It is therefore important that the **aggregation process itself satisfies specific quality criteria** keeping in mind the intended use of the resulting index, and keeping in mind the quality criteria of the indicators: policy relevance, analytical soundness and measurability.

Aggregation steps

Selection of variables that are representative of the topic, policy issue or phenomenon of interest

Transformation into a common metric. This is necessary when the selected **variables** do not have the same dimension and to ensure that changes in one variable do not dominate those of the others in the final index.

Weighting of the constituent variables. This is the process of judging the relative importance of various components of an index. Weighting can be carried out in several different ways. It should be noted that, apart from this explicit weighting process, the procedure for selecting variables has already introduced an implicit weighting to each variable.

Valuation. This means comparing the indices with a pre-determined **classification** of what constitutes good or poor values. It is commonly used to present air quality indices to the public.

- The aggregation process must be completely transparent, i.e. every step in the process should be traceable. Users should be aware of all assumptions and choices made in terms of weighting, how missing data have been imputed, etc.
- The variables to be grouped should be independent, i.e. not show cause-effect relationship.
- All components of an index should be part of the problem and amenable to change in response to human intervention (e.g. although temperature is an important factor in ozone formation, it is not a valid component of an air quality index).
- All components of an index should show about the same order of magnitude.
- The variables being aggregated should be situated at the same step in the cause-effect chain. For instance, it is acceptable to aggregate fertilisers and pesticide use, but not together with biological oxygen demand or biodiversity of species. This rule also excludes the aggregation of pressure and state indicators.
- The conversion (transformation) of indicators prior to their aggregation with other indicators should follow certain explicit rules. Also, the rules for comparing the results should be defined before selecting an aggregation method (because the choice of aggregation method affects the message conveyed).
- Weighting factors needed to aggregate indicators from different categories or themes (which are difficult to compare using the tools of the natural sciences) need to be set with the help of tools from the social sciences.
- Never combine objective (i.e. by way of accepted methods used by the natural and social sciences) and subjective weighting methods in the same step of aggregation.
- An index should be tolerant to inconsistencies arising from aggregation and valuation.

As for other indicators and depending on their purpose, additional information and interpretation in context is required fro aggregated indices to acquire their full meaning.

Source: OECD (2002), Aggregated Environmental Indices – Review of Aggregation Methodologies in Use.

5. PURPOSES AND USES OF MATERIAL FLOW INDICATORS

The sections below describe the various issues to which material flow indicators relate and give examples of indicators derived from MFAcc and other statistics for each of these issues. The list of indicators given is not exhaustive, but illustrative. It may evolve as data quality improves and as more feedback from using these indicators becomes available.

5.1. Monitor the material basis of national economies and industries

Monitoring the physical scale or materials basis of an economy requires indicators that reflect the level and characteristics of the use of materials in the economy (or in industries and process chains), whether for own final use or for exports and use by external markets. The use of materials can refer to material inputs, material requirements, or material consumption.

The data sources for indicators that reflect the material basis of an economy include:

- **Simple economy-wide MF accounts** focusing on the input and consumption side, broken down by material groups and flow types.

The indicators can be directly based on major MF accounting variables (input and consumption). They can be expressed in absolute values or be normalised by relating them to population data. These indicators group materials in mass units (usually tonnes). Examples are: direct material inputs (DMI), total material requirements (TMR), domestic material consumption (DMC) or total material consumption (TMC).

5.1.1 Interpretation and limits

The interpretation of indicators reflecting the materials basis of an economy varies depending on the natural resource base and the economic structure of a country, and on the purpose for which the indicators are used.

These indicators are sometimes used as proxies for the generic environmental pressure associated with the use of materials for production and consumption purposes. This is based on the assumption that sooner or later every material input becomes an output in the form of waste or emissions, and that measuring the inputs therefore gives a rough approximation of the overall environmental burden. This should however not be interpreted as reflecting actual or specific environmental impacts.

Indicators reflecting overall material basis are particularly useful to give an overview of opportunities and problems in material and energy flows, attract attention to key trends and changes, and support broader policy goals. They are most relevant when paired with indicators describing resource productivity or intensity ratios, and when complemented with trade related indicators.

The information value of the indicators is greatly enhanced when they are associated to objectives or targets such as those included in national sustainable development strategies or circular economy programmes, when they show the structure, i.e. the materials mix, of an economy's material basis, and when they show the relative weight of different industries in materials use and related shifts among industries and over time.

5.1.2 Materials mix and mode of materials use

The materials mix is represented by indicators broken down by materials that are grouped by common characteristics. This helps see the weights of different types of materials in the material basis of the economy and how these weights change over time. Depending on the characteristics chosen to group the materials, the information value of the indicators changes.

- The most common way to reflect the materials mix is to use basic material groups as they appear in MF accounts. This results in the presentation of five up to 12 major material groups: metals (metallic ores and metal-based products), non-metallic industrial minerals, construction minerals, fossil energy carriers (oil, coal, gas, others such as peat), biomass (food crops, fodder crops, timber, wild animals, other). The level of detail chosen has to be adapted to the audience of the indicators. In general the number of categories shown in a breakdown should not be too big, so that users can easily capture them when expressed in the form of graphics.
- The materials mix can also show materials grouped by type of natural resource from which they are extracted, such as materials from renewable natural resource stocks versus materials from non-renewable natural resource stocks, or abiotic materials versus biotic materials. The indicators then monitor ratios of renewable materials in particular indicators, such as the share of renewables in direct material inputs (REN/DMI) and/or in total material requirements (REN/TMR). Such indicators have been used to reflect the fact that, with current technologies and in the absence of appropriate recycling, the use of non-renewable materials is often associated with comparatively higher negative impacts on the environment, and that an appropriate balance between materials from renewable and non-renewable resources in the materials supply is needed (EEA, 2005).
- The characteristics chosen can also focus on the type of flow and mode of use of the materials. Some materials are used in production and consumption processes, while others are only costly moved, without being used and do not contribute to economic value added. Examples of indicators are the volume of unused domestic extraction (UDE), the share of UDE in a country's total material requirements (UDE/TMR) and the share of domestic extraction used (DEU) in TMR (DEU/TMR). Distinguishing between used and unused flows in the materials basis of an economy or an activity is useful from an environmental point of view because the environmental pressures associated with used and unused flows may differ. It is useful from an economic point of view because reducing unused material flows may help increase the economic efficiency of material production.
- Finally, materials can be grouped by considering the type of pressure they exert on the environment and hence their potential environmental impacts. A distinction can thus be made between materials that may lead to toxic contamination and affect human and ecosystem health, materials that are linked to specific pollution issues (air, water, soil pollution), and bulk materials whose extraction and use may lead to habitat disruption, landscape changes, etc. (section 5.5.1).

5.1.3 Problem shifting among industries

The relative contribution of different sectors and industries to the overall consumption of materials and the overall production of emissions and wastes differ significantly and change over time. A decrease in material consumption of a particular industry can thus be offset by an increase in consumption of other industries, and result in a shift of problems related to this consumption instead of mitigating them. To study this shifting and to identify the sectors and industries that contribute most to material consumption, it is advisable to use MF indicators that are broken down by major economic activity sector.

The data sources for indicators that reflect the structure of the material basis by economic activity sector include:

- **Physical input-output tables** and NAMEA-type accounts for data inputs showing a breakdown of national material use by industry or the material basis of particular industries.
- **Extended economy-wide MF accounts** broken down by economic activity

The sectors covered should be aligned with the International Standard Industrial Classification of All Economic Activities (ISIC), and include at a minimum agriculture and forestry, mining and quarrying, manufacturing industries, construction, and other activities. Depending on the purpose, households, the energy sector or the transport sector may be relevant.

5.2. Monitor the material productivity of national economies and industries

Capital and labour are not the only inputs into a production process or an economic activity that determine productivity performance. Natural resources and materials constitute a large part of the inputs and of the cost structure of most goods and services. The efficiency with which these resources are used has a bearing on overall productivity, on the pollution and waste intensity of production processes and on the security of supply of strategic and rare materials.

Monitoring the material productivity requires indicators that reflect the intensity of use of materials in the economy or in industries and process chains, and that can be linked to productivity issues, to eco-efficiency measures, and to technology development and innovation.

5.2.1 Terminology and calculation methods

Definitions and terminology

The terms productivity and efficiency refer to different but related concepts. Productivity relates the quantity of output produced to one or more inputs used in the production of the output, irrespective of the efficiency of their use. In this guide, the term "efficiency indicators" is used in a generic way covering both productivity and intensity ratios. One distinguishes:

- Productivity indicators that reflect resource or material productivity at national, industry or plant level and that parallel those describing labour or capital productivity.
- Intensity indicators that reflect the intensity of use of natural resources or materials at national, industry or plant level. Intensity indicators are the inverse of productivity indicators.
- Decoupling indicators that describe the level of coupling or decoupling between economic growth or industrial activity and developments in natural resource and materials use and in the associated environmental pressures.

The terms resource productivity and material productivity are often used as synonyms, even though the related indicators usually do not cover all resources. Resource productivity would ideally encompass all natural resources and ecosystem inputs that are used as factors of production in the economy. For practical reasons this guide focuses on indicators that can be derived from MFAcc and that usually do not cover water resources.

> The data sources for material productivity and intensity indicators include the following:
>
> - At a general level, flow relations from **Economy-wide and other national MF accounts**.
> - At a more detailed level, for example at industry level, data from **Physical input-output tables** and NAMEA-type tables.
> - **Environmental and hybrid input-output analysis** (IOA) is used to attribute direct and indirect material inputs and residual outputs to industrial sectors based on the economic relations provided by monetary IO tables.
> - In some cases, the original data sources underlying material flow accounts can be used (e.g. **industrial production statistics, production accounts**).

Calculation methods

There is no standardised methodology for calculating material productivity. Like other productivity measures, it can be defined in various ways depending on the purpose for which it is to be used.

Material productivity makes reference to the effectiveness or efficiency with which an economy or a production process is using materials extracted from natural resources. It can be defined with respect to:

- the economic-physical efficiency, i.e. the money value added of outputs per mass unit of material inputs used. This is also the focus when the aim is to decouple value added and material consumption.
- the physical or technical efficiency, i.e. the amount of material input required to produce a unit of output, both expressed in physical terms (e.g. iron ore inputs for crude steel

production or raw material inputs for the production of a computer, a car, batteries). The focus is on maximising the output with a given set of inputs and a given technology or on minimising the inputs for a given output.

- the economic efficiency, i.e. the money value of outputs relative to the money value of inputs. The focus is on minimising material input costs.

Table 9. Overview of the main productivity measures

Productivity is commonly defined as a ratio of a volume measure of output to a volume measure of input use. While there is no disagreement on this general notion, productivity can be measured in various ways and for various purposes. When only one input is included in the denominator, the indicator is a single-factor productivity measure. When a range of inputs is included, the indicator is a multi-factor productivity measure.

Type of input measure / Type of output measure	**Labour**	**Capital**	**Capital and labour**	**Capital, labour & intermediate inputs** (energy, materials, services)
Gross output	Labour productivity (based on gross output)	Capital productivity (based on gross output)	Capital-labour MFP (based on gross output)	KLEMS multi-factor productivity
Value-added	Labour productivity (based on value-added)	Capital productivity (based on value-added)	Capital-labour MFP (based on value-added)	–
	Single factor productivity measures		**Multi factor productivity (MFP) measures**	

Source: Measuring Productivity - OECD Manual: Measurement of Aggregate and Industry-Level Productivity Growth, OECD, Paris, 2001.

5.2.2 Material productivity of national economies

Indicators reflecting the resource or material productivity are particularly useful to:

- Monitor the decoupling of material resource use from economic growth;
- Compare different levels of material resource use and productivity between countries and serve as a basis for further research to reveal the factors responsible for the differences);
- Identify those sectors that are material intensive and hence often also emission intensive and that face particular challenges with respect to material productivity and sustainable resource use;

Productivity is generally measured within the production boundary of the system of national accounts (SNA). Whatever type of analysis is made, the choice of the numerator and denominator of the ratio is crucial, as is the statistical coherence between the two, i.e. the degree to which they are logically connected and mutually consistent.

In principle, MF input, consumption and output variables can all be related to national account aggregates to study the economic efficiency or the productivity of material use. In practice, material productivity indicators refer more to the input and consumption sides of the national economy.

- By relating MF input and consumption variables to national account aggregates, such as GDP, one can measure the efficiency by which an economic system transforms materials into economic output. These indicators generally focus on overall material flows or on material groups and can easily be derived from simple EW-MF accounts. They can be paired with energy intensity or productivity indicators relating total primary energy supply (TPES) or total final consumption of energy (TFCE) to GDP.

  Since consumption variables are the closest equivalents to national accounts aggregates, their use in productivity ratios is rather straightforward, but their interpretation may be hampered by a lack of internal coherence when broken down by material groups. (section 4.3.1)

When using input variables, such as DMI or TMR that include imports but do not consider exports, it is advisable to also add imports to the numerator for a better correspondence to the national account aggregates, e.g. (GDP+IMP)/TMR. Depending on whether direct and indirect flows are considered the adequate economic indicator needs to be chosen.

Indicator examples include:

- Domestic material productivity that is defined as the ratio between gross value added (at constant prices) and the domestic material consumption of a country (GDP/DMC). It describes the amount of materials consumed in an economy to generate one unit of gross domestic product, excluding the materials that have been incorporated in exports.
- Total material productivity that is defined as the ratio between gross value added or GDP (at constant prices) and the total material requirements of a country (TMR) (GDP/TMR). It describes the total amount of materials extracted, moved or used to generate one unit of gross domestic product. Total material productivity is the most complete indicator from an environmental point of view, but is difficult to measure due to the inclusion of unused and indirect flows.
- Direct material productivity that is defined as the ratio between gross value added or GDP (at constant prices) and the direct material inputs of a country (DMI) (GDP/DMI). It describes the amount of materials used as inputs in the economy to generate one unit of gross domestic product, including the materials that have been incorporated in exports.
- Raw material productivity: Raw material productivity is defined as the ratio between gross value added (at constant prices) and the sum of raw materials extracted in the country (considering the portion actually used) and imported materials in the form of raw materials (GDP/RMI). It can be calculated separately for biotic and abiotic materials, i.e. for materials that stem from renewable resource stocks (e.g. those related to agricultural or forestry products) and for materials that stem from non-renewable resource stocks (e.g. metals). It describes the efficiency with which raw materials are used in the national economy and has similarities with indicators on labour and capital productivity.

- By relating MF output (to nature) variables to national account aggregates, one can measure the volume of residual output flows discharged into the environment per unit of economic output, thus reflecting the pollution and waste intensity of an economy. These indicators generally focus on overall material flows or on material groups and can be derived from complete EW-MF accounts or from material flow balances. Examples include: GDP/TDO that reflects the economic performance with respect to the materials lost to the environment. Practical experience with such indicators is limited, because MFacc established in countries do not always cover the full material balance.

5.2.3 Material productivity of industries

To study the productivity of material use of particular economic activity sectors or industries, the indicators can be based on MF variables broken down by these sectors and related to the appropriate economic variables, i.e. the gross value added of these sectors. All indicator examples given above can be equally applied at sectoral level or to particular industries. They can be used to:

- Show structural changes in material productivity at national level, and differentiate among industrial sectors that may exhibit differences in material and resource productivity (benchmarking);
- Point at opportunities and inefficiencies in energy and materials use in specific sectors.

When supported with further analyses or coupled with economic models, they help:

- Model the improvement of material efficiency of relevant sectors, e.g. manufacturing, which can be used to assess the environmental effectiveness and economic efficiency of potential policy measures (e.g. economic instruments).
- Understand the differences between countries and groups of countries with regard to expected future changes in the course of technological and socio-economic development.
- Monitor sectors of intermediate and final demand by considering direct and indirect material and resource requirements, and provide a basis to setting priorities for improved resource and product management and identifying the actors to be involved.
- Monitor the future use of material resources and progress towards increased resource productivity according to business-as-usual or alternative scenarios.

The calculation of indicators monitoring the material productivity of particular industry generally requires the existence of detailed MF accounts broken down by economic activity sector. Direct material input and waste generation can be attributed to sectors on a NAMEA[39] basis. To gain a complete picture of the physical interrelations of sectors physical input-output tables (PIOT) are needed; this however requires significant efforts for a first implementation and a regular update. Environmentally extended or "hybrid" input-output analysis (eIOA) is therefore often used to attribute direct and indirect resource/material inputs and waste/emission output to industrial sectors based on the economic relations provided by monetary IO tables. The results show the amount and type of material resources or emissions induced by the volume of economic activities. Setting induced MF input or consumption in relation to economic output indicators may then provide information on the resource productivity of the different economic branches. (Box 7).

At the product level, the use of a service unit instead of the monetary value added as the numerator may be more adequate. An example is Material Input per Service Unit (MIPS)[40]. MIPS estimates the overall consumption of natural resources or materials by a product or a service over its whole life-cycle from cradle to cradle (extraction, production, use, disposal/recycling) and is seen as a proxy for the overall potential environmental burden of a product or a service. The MIPS indicator is usually applied at the micro-level, where it focuses on specific products and services. It accounts for the cumulated primary resource requirements for the categories (i) abiotic raw materials, (ii) biotic raw materials, (iii) soil and earth movements, (iv) water and air (the first three categories may be combined to provide TMR). MIPS can also be applied at the macro-level, where it is consistent with total material productivity based on TMR.

Another useful indicator at industry or company level is the material labour productivity, expressed as the material output in physical terms per worker. It can give insights into the relationship between material productivity and the economic labour productivity (value added in monetary terms per worker).

39 National Accounting Matrix including Environmental Accounts.
40 Ritthof et al., Wuppertal Spezial 27, Wuppertal Institute.

5.2.4 Decoupling materials use from environmental pressure

Relating MF variables to national account aggregates to monitor material productivity is complementary to the decoupling analysis, which studies whether and to what extent environmental pressure[41] exerted by socio-economic entities (national economies or industries) on the environment decouples from economic growth.

> **Decoupling** refers to breaking the link between "environmental bads" and "economic goods." Decoupling occurs when the growth rate of an environmental pressure is less than that of its economic driving force over a given period. Decoupling can be either absolute or relative. **Absolute** decoupling is said to occur when the environmentally relevant variable is stable or decreasing while the variable reflecting the economic driving force is growing. Decoupling is said to be **relative** when the growth rate of the environmentally relevant variable is positive, but less than the growth rate of the variable reflecting the economic driving force.
>
> *Source*: OECD (2002).

The variables that feature in decoupling indicators also appear in material productivity and intensity indicators. Decoupling is usually conceived as an elasticity focusing on changes in volumes, whereas productivity and intensity are more concerned with the actual values of these ratios. In the MFA context, the difference between decoupling and productivity or intensity indicators is rather a matter of presentation, with decoupling indicators always being shown as two separate lines for the numerator and denominator, whereas productivity or intensity indicators are shown as a single line representing the quotient of the two. Which usage is chosen depends on the context and, often, on the audience being addressed.

Table 10. Overview of selected material productivity and intensity measures

Type of input measure / Type output measure	***Direct Material Input or Raw Material Input***	***Total Material Requirement (incl. indirect flows)***	***Domestic Material Consumption or Raw Material Consumption***	***Total Material Consumption (incl. indirect flows)***
GDP, Value added	Direct Material Productivity GDP/DMI Direct Raw material Productivity GDP/RMI	Total Material Productivity GDP/TMR	Domestic Material Productivity GDP/DMC Domestic Raw Material productivity GDP/RMC	Total Domestic Material Productivity GDP/TMC
Domestic Processed Output (emissions & waste)	DPO/DMI	DPO/TMR	DPO/DMC DPO/RMC	DPO/TMC
Total Domestic Output (emissions, waste, unused extraction)		TDO/TMR	TDO/DMC TDO/RMC	TDO/TMC

Note: The choice of the appropriate input and output measure needs to take into account the statistical coherence between the two. Adjustments to the economic variable may be required depending on the MF variable used.

Source: OECD.

5.2.5 Interpretation and limits

The interpretation of material productivity indicators varies depending on the natural resource base, the economic structure of a country and the level of technology development and innovation.

National level indicators reflecting overall material productivity are particularly useful to give an overview of opportunities and problems in material and energy flows, attract attention to key trends and changes, and support broader policy goals. When indicators are to be used in decision-making or for productivity analysis, they are more relevant when broken down by economic activity sector, by materials or material categories (where in turn they appear to be most relevant when applied to non

41 The actual purpose is to study the decoupling between economic growth and environmental degradation. For practical reasons, the quantitative assessment of decoupling and related indicators focus on environmental pressures that are easier to measure and can be more easily related to the underlying economic driving forces.

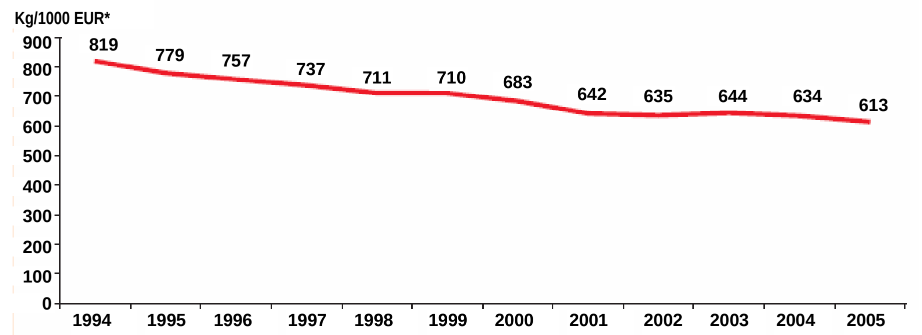
renewable resources such as metals, other minerals or fossil fuels), and when they are applied to entities at the meso and micro-levels (industries, plants, process chains). They can usefully be complemented with indicators measuring the productivity of selected material resources or material groups (energy efficiency, minerals efficiency) or the efficiency of product use.

In order to get a better understanding of the reasons for the differences between countries, the values of the RP indicators need to be supplemented by other indicators and more detailed information. RP indicators can be usefully paired with indicators describing the material basis of an economy or an activity. The absolute values of resource use (the denominator) and GDP or value added (the numerator) and their trends can be used to show which part of the ratio is responsible for the RP performance. Sometimes the use in parallel of different denominators or numerators is recommended.

Measures of material productivity extend productivity measurement and analysis to material resources and complement existing productivity measures like labour productivity or capital productivity. Considering those indicators in parallel conveys a more thorough and comprehensive information on total factor productivity than relying on only one or two of those indicators. It also helps enhance the relevance and credibility of resource or material productivity indicators for economic policies, and relate them to competitiveness issues and to technological change and innovation. Such indicators can also be used to monitor and encourage waste prevention and recycling, sustainable materials management, or integrated product policies at a general level (3R related policies and measures), and are of relevance to economic and industrial policies.

Box 7. Monitoring resource productivity: Indicator examples

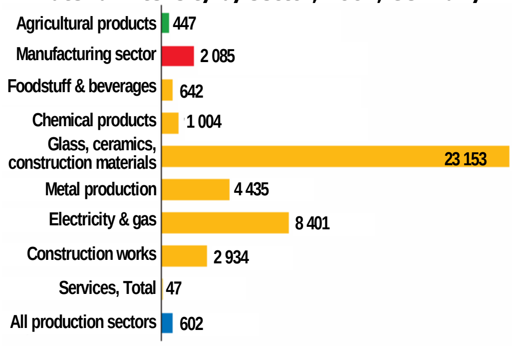
Raw material intensity, 1994-2005, Germany



* *Price adjusted, interlinked volume*

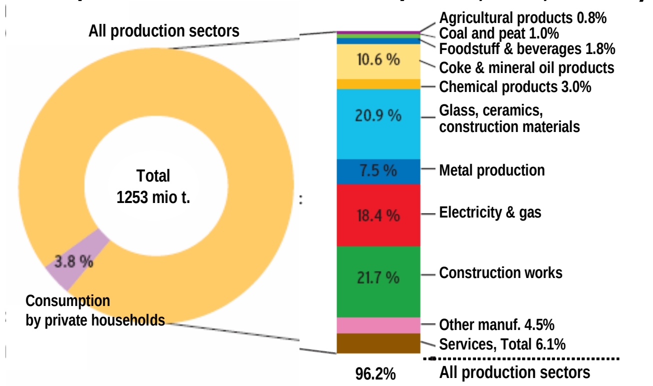
Source: UBA, Destatis, 2007

Material intensity by sector, 2004, Germany



* kg material input/1000 EUR gross value added (at respective prices)

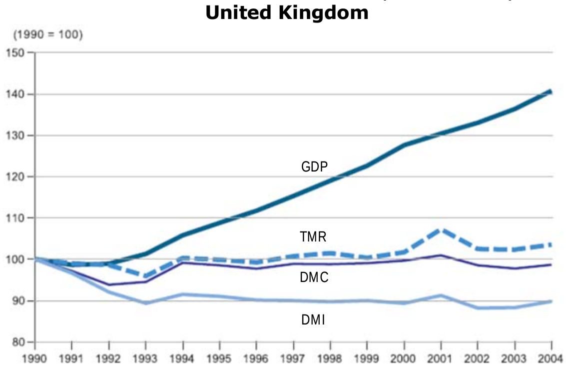
Consumption of abiotic raw materials by sector, 2004, Germany



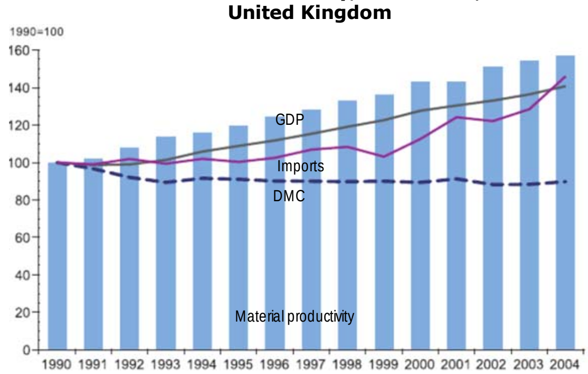
In this example, the direct material inputs from domestic primary sectors and from imports were attributed to the receiving branches representing the second stage of use in the production and consumption chain. The amounts of abiotic materials used were then related to the gross value added of the branch to benchmark material intensity, i.e. the inverse of (direct) material productivity. A comparison over time allows to record those branches, which reduced or increased their material intensity.

Source: UBA, Destatis, 2007

Resource use in relation to GDP, 1990-2004, United Kingdom



Material Productivity, 1990-2004, United Kingdom



In this example, three different indicators (DMI, DMC, TMR) are used to compare trends in the material basis of the economy with GDP growth. The first figure shows a decoupling between trends in material resource use and trends in GDP. The second figure shows gains in material productivity over time. It also shows that in recent years imports of materials (in weight) increased faster than GDP. As "hidden flows" associated to imports are relatively important, this can explain the weaker decoupling in TMR over the period, whereas DMC experienced an absolute decoupling from the economy (left figure). This also suggests that some of the environmental impacts associated to consumption in the UK are progressively transferred abroad.

Source: UK Environmental Accounts, Office for National Statistics, 2005

5.3. Monitor the implications of trade and globalisation for material flows

Monitoring the implications of trade and globalisation for material flows can be done in various ways. It requires indicators that capture international movements and trade in materials i.e. flows of materials among countries and among different parts of the world.

The type of materials to be covered by the indicators depends on the issue to be addressed. The indicators can cover all materials or groups of traded materials ranging from raw materials and semi-finished goods to materials embodied in finished goods. They can also cover recyclable materials or materials raising special concerns such as hazardous materials, waste, or pollution intensive materials.

Indicators that capture international flows of materials help monitor the interactions and interdependencies among countries and world regions by measuring the weight of a group of countries in global resource flows, the material security of countries, and the level of foreign resource use by domestic economic activities. They can be linked to issues of foreign outsourcing and competitiveness, to demand and supply issues, to international market prices of raw materials, including energy, and to trade in recyclable materials and reprocessed goods. They also help identify the extent to which the environmental consequences of the production and consumption of natural resources and materials of a country or a group of countries extend beyond their borders, where the associated environmental burden is located and how it shifts between countries and world regions.

Trade related MF indicators can be used to:

- Quantify the dynamics of the dependence on foreign resources (supply security; outsourcing), and measure the (im-)balance between imports and exports (including hidden or indirect flows);
- Indicate shifts in environmental pressure associated with material and resource flows between countries and world regions.
- Monitor environmentally harmful materials or substances embedded in imports and exports.
- Point at risks related to international transport/movements of dangerous materials or waste.
- Monitor trade in recyclable materials at global and regional level.

Data sources

The data input needed to calculate such indicators comes from national material flow accounts and/or directly from trade and production statistics. EW-MFAcc for example account for import and export flows of materials, but rarely for the origin and destination of these flows. Calculating indicators that reflect shifts in material flows among countries and regions thus requires an expansion of the accounts or the direct use of trade statistics expressed in physical terms.

The indirect flows associated with imports and exports may be reported in raw material equivalents, TMR equivalents, or in GHG emission equivalents, depending on the purpose of the resulting indicators. The subcategories used for foreign resource extraction/harvest (biomass, metallic minerals, industrial minerals, construction minerals) should fit the categories used domestically.

> The data sources for indicators that reflect international flows of materials include:
>
> - Extended **economy-wide MF accounts** showing a breakdown of trade flows by origin and destination.
> - **Physical and monetary input-output tables** and analyses.
> - Trade and production statistics
> - Waste statistics (transboundary movements of hazardous and other waste, flows of recyclable materials.

Indicators monitoring international trade flows of materials can also be derived from physical and monetary input-output analysis accounting for interactions among countries. Such indicators and the associated analysis are particularly useful to point at developments related to globalisation and the

increasing mobility of production factors. Other useful data sources include waste statistics, i.e. data on transboundary movements of hazardous and other waste, flows of recyclable materials.

Data are readily available for the calculation of basic indicators on trade flows (exports, imports, physical trade balance). Indicators covering indirect flows associated with imports and exports require further development in terms of data availability and quality and from a methodological point of view. Several methods to calculate indirect flows have been developed; their respective strengths and limitations need to be further reviewed so as to give better guide practitioners. Little information is available on recycled or recyclable materials.

5.3.1 Material dependency and supply security

Economies fulfill their material demands partly from their own territory and partly by importing materials from other countries. The expansion of international markets and of trade makes production processes in many countries becoming more dependent on external sources of inputs and/or on demands in markets located in other countries.

The higher the import share in domestic material input and domestic material consumption, the more the economy is dependent on material inputs from abroad, and the more the economy is sensitive to incidental shortage of particular commodities abroad, increases in their market price or upheaval of other barriers to foreign trade. The higher the share of domestic extraction, the more the economy fulfils its material demand from its own territory. The higher the export share, the more the economy is sensitive to changes in demands from external markets and changes in international market prices. Monitoring these characteristics is particularly important for strategic or rare material resources, such as metals and metal ores, other industrial minerals, fossil fuel carriers, and certain agricultural commodities.

Examples of foreign material dependency indicators are:

- The share of imported materials in domestic material inputs or consumption (IMP/DMI; IMP/DMC).
- The share of imported materials and/or indirect flows of imported materials in total material requirements (IMP/TMR; IF_{IMP}/TMR; (IMP+ IF_{IMP})/TMR) or the share of imported materials and/or indirect flows of imported materials in total material consumption (IMP/TMC; IF_{IMP}/TMC; (IMP+ IF_{IMP})/TMC).

Examples of domestic material dependency indicators are:

- The share of domestic material extraction in domestic material inputs or consumption (DEU/DMI; DEU/DMC).
- The share of domestic material extraction (used and unused) in the total material requirements of a country or in the total material consumption ((DEU+UDE)/TMR; (DEU+UDE)/TMC).

These indicators can be calculated at an aggregate level or for particular materials or material groups. They can be complemented with indicators derived from trade (and production) statistics expressed in physical units and can be paired with trade indicators in monetary units to give further insights.

5.3.2 Regional specialisation and material intensity of trade flows

Countries are at varying stages of socio-economic and industrial development and present different levels of endowment in natural resources. Due to increased regional specialisation, many industrialised economies import materials with low value added such as raw materials and export highly processed and technologically sophisticated products with high value added (e.g. certain countries in Europe, Japan). The inverse situation can be found in countries that are rich in natural resources. This is the case in many developing countries, but also in resource rich industrialised countries (e.g. Australia,

Canada, Norway). Monitoring these characteristics by looking into the material intensity of exports and imports (i.e. the material weight of imports and exports, in physical terms, compared to the value of imports and exports, in monetary terms) reflects the development stage of an economy in terms of its industrial base and the technologies used, the qualification of its workforce and the international division of labour.

Examples of indicators reflecting the material intensity of trade flows are:

- Material intensity ratios, i.e. the material weight of imports (IMP) and exports (EXP), in physical terms, compared to the value of imports (M) and exports (X), in monetary terms (IMP/M; EXP/X).
- Raw material intensity ratios, i.e. the raw material equivalent of material imports and exports in physical terms, compared to the value of imports and exports, in monetary terms (RME_{IMP}/M; RME_{EXP}/X).

The lower these ratios are, the comparatively more processed and technologically sophisticated products are traded.

5.3.3 Problem shifting between countries and world regions

Many industrialised countries have decreased the amounts of domestically extracted and processed materials by importing them from other countries. This has shifted the potential environmental pressure associated with the extraction and processing of these materials to the producing countries that are often developing countries or resource rich developed countries. These shifts can be captured by studying the physical trade balance and the physical trade flows (imports and exports) of materials by country or region of origin and destination.

Useful indicators that can be derived from MFAcc include:

- The raw material equivalents of imports and exports (RME_{IMP}; RME_{EXP}) or the indirect flows of materials related to imports and exports (IF_{IMP}; IF_{EXP}).
- These indicators cover also up-stream flows related to foreign trade and are thus better proxies for the environmental burden related to the production of these imports and exports than indicators reflecting the imports and exports alone.
- The physical trade balance (PTB) without and including indirect flows can be analysed to indicate the trends of foreign resource use by domestic economic activities, and the resulting implications of growing globalisation and outsourcing. Sub-samples of the PTB can be provided for selected product groups of special interest, for example to monitor the dynamics of dependence of certain raw materials, or to indicate the shift of pollution related environmental pressure to other regions. When used to reflect the net import of environmental pressure related to foreign trade, the calculation of the PTB should not be limited to imports and exports, but should account for the raw material equivalents (RME_{IMP} and RME_{EXP}) or for the indirect flows (IF_{IMP} and IF_{EXP}) respectively. A differentiation of trade flows according to delivering and receiving countries allows region or country specific interpretation of the results.

When setting up a foreign trade balance for selected substances through estimating the substance content of imports and exports (e.g. heavy metals, nutrients), the resulting indicators may only be interpreted appropriately in the context of a full SFA considering all other relevant flows as well.

Other useful indicators include:

- Indicators on transboundary movements of waste (hazardous waste, waste going to recycling),

- Indicators on the transport of hazardous materials and goods (by mode of transport: road, sea, air, pipeline).

The data needed to calculate these indicators are not captured in conventional trade statistics nor in MFAcc, and need to be obtained from other data sources.

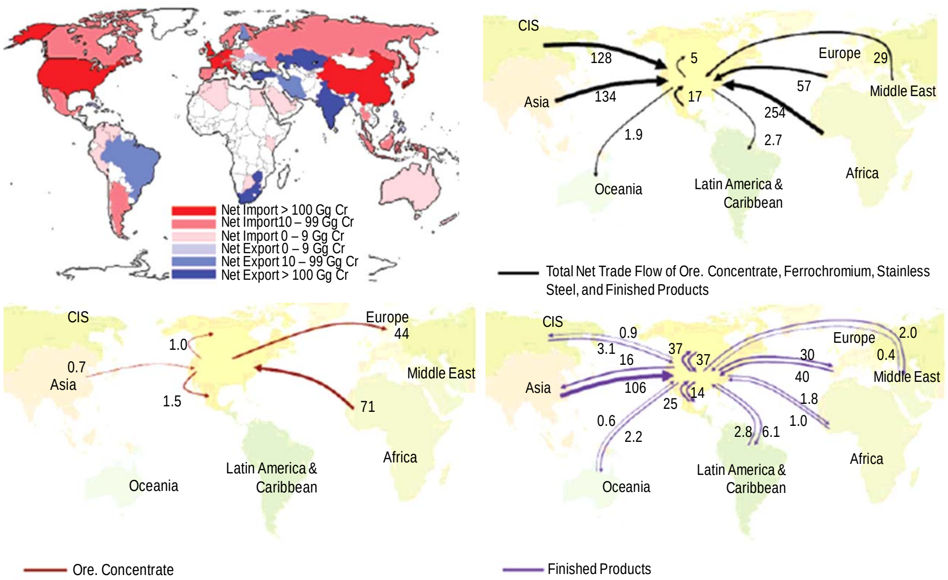
5.3.4 Interpretation and limits

Trade related MF indicators can be calculated at an aggregate level or for particular materials or material groups. At an aggregate level, such indicators are more descriptive in nature, and need to be related to reference values to gain significance. They are particularly useful when paired with basic MF indicators such as DMC or DMI or with material productivity indicators. They can be usefully be associated with "conventional" trade and foreign investment statistics and, when appropriate, with data on transboundary movements of waste.

The limits of these indicators, and general recommendations for their interpretation and use are similar to those for other types of MF indicators. It is recommended to accompany them with additional contextual information to ease interpretation and to break aggregated indicators down, whenever possible, by a minimum of material categories. This is important for example when the indicators are to be used to monitor shifts in environmental burden due to changes in trade flows and foreign outsourcing, but also to point at developments that could affect the supply security of strategically important materials. Such indicators appear to be particularly relevant when applied to selected materials that are of economic and environmental significance. The development of more specific guidance requires further review.

Box 8. Monitoring the implications of trade and globalisation: Indicator examples (1)

International trade of chromium, focus on the United States and its major trade partners, 2000



This example stems from the Stock and Flows (STAF) project of the Yale University (USA). It shows the regional disparities in demand and supply of chromium resources. Then it shows, as an example, the level of dependence of the United States on chromium supply in the following forms: ore and concentrate from Africa, and finished products from Asia.

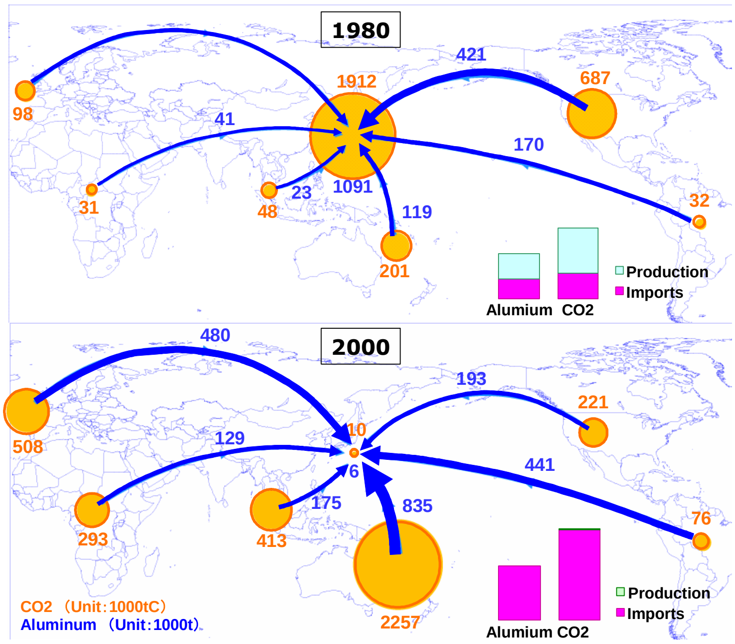
Note: Total net trade includes (a) Net trade of chromium in ore, concentrate, ferrochromium, semi-finished products, finished products, and scrap; United States' trade of chromium in (b) ore and concentrate; (c) ferrochromium; (d) stainless steel (semi-finished); (e) finished products. All values are given in Gg Cr/yr.

The study reveals that net suppliers of chromite ore are geographically more concentrated than the net importers of chromium resources. Nearly 90% of the mined chromite ore (measured as contained chromium) comes from five countries: South Africa, Kazakhstan, India, Zimbabwe,and Turkey. On the other hand, the net importing countries are a broader group, of which the top seven make up two-thirds of the total net imports of chromium and are, in descending order, the United States, Japan, China, France, Germany, United Kingdom, and Italy. Thus, impacts of trade disruptions can be anticipated. According to the authors, although historic trade relations between the exporting and importing countries have proven to be stable, political unrest or other episodic incidents in major producer countries could lead to global price spikes or to shortages.

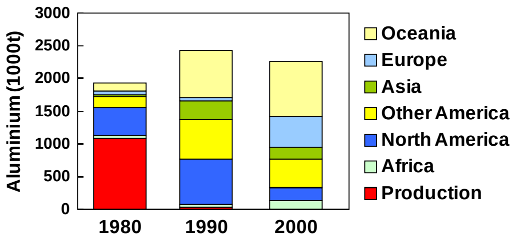
Source: Johnson, Schewel and Graedel (2006).

Box 9. Monitoring the implications of trade and globalisation: Indicator examples (2)

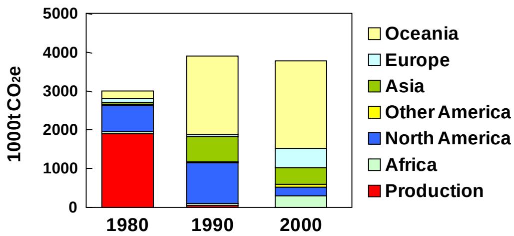
Domestic production and import of primary Aluminium and related CO2 emissions, 1980-2000, Japan



Domestic production and import of Aluminium



CO2 emissions for Aluminium requirements



Source: NIES

This example shows the growing dependence of the Japanese economy on imported primary aluminium from 1980 to 2000, and the developments in CO_2 flows associated with the extraction and processing of aluminium ores at home and abroad by region of origin.

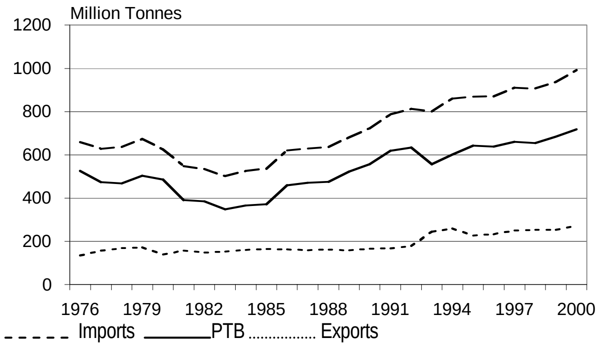
Physical trade balance, 1976-2000, European Union

	PTB in DMIeq		PTB in TMReq	
	10^6 tonnes 2000	% change 1976-2000	10^6 tonnes 2000	% change 1976-2000
Biomass from				
-- agriculture	25,4	-61%	245,7	-57%
-- forestry	40,3	8%	107,7	8%
-- fishing/hunting	2,0	268%	2,6	270%
Fossil fuels	704,1	30%	1821,5	106%
Metals, metal products	146,1	30%	3829,1	194%
Minerals, mineral products	22,7	121%	254,1	221%
Other products	65,8	-1.141%	65,8	-1.141%
TOTAL	**1006,4**	**32%**	**6326,6**	**114%**
Renewable materials	67,7	-35%	356,0	-47%
Non-renewable materials	872,9	32%	5904,8	161%

DMIeq: PTB = Imports – Exports (considers only direct flows);
TMReq: PTB = TMRimp – TMRexp (considers direct, indirect and unused flows)

Source: Schütz et al., 2004

Physical trade balance of pollution intensive goods*, 1976-2000, European Union



* Iron and steel, non-iron metals, chemicals (industrial and other), mineral fuels, non-metallic mineral products, cellulose and paper, rubber goods, leather goods and metal goods; according to a rough categorisation by Mani and Wheeler (1997).

Source: Schütz et al. 2004

This example shows the extent to which the European Union relied on net imports to cover its material needs in 2000 and how this has evolved over time. When accounting for direct flows only by using DMI equivalents, the trade balance grew by 30% since 1976. When accounting for hidden flows by using TMR equivalents, the trade balance more than doubled. This points to the increasing reliance of production and consumption in the EU on foreign material resources, with a probable shift in resource related environmental pressure abroad. Growing hidden flows are mainly due to increased net imports of fossil fuels and metals (30% each) whose TMR equivalents grew by 106% and 194% respectively. These developments were accompanied with an increasing net import surplus for pollution intensive goods.

5.4. Monitor the management of selected resources and materials

Indicators characterising individual material flows are useful to support issue specific decision making and resource management and to complement other natural resource and pollution indicators already in use. They are of value to policies and decisions in areas such as waste and materials management, the 3Rs, integrated pollution prevention and control, control of toxic substances and hazardous waste, as well as to polices and decisions in areas such as technology development and innovation, and international trade.

There is a large array of issues that substantiate the monitoring of resource and material flows of particular interest. On a country level, the selection of these flows is influenced by factors among which:

- the contribution of certain flows to specific environmental impacts,
- the scarcity at national level and/or high foreign trade dependency for particular materials,
- raw material prices,
- the importance of particular materials for country specific industrial branches,
- the recycling potential of particular materials,
- the waste treatment capacity for particular materials, etc. .

Monitoring the management of selected natural resources is important especially when considering the intensity of resource use with respect to available natural resource stocks. Monitoring the management of selected materials and substances is important when considering the environmental effects of materials use or the efficiency with which certain materials or waste flows are managed. Since the choice of the material to be monitored results directly from the specific policy or management concern, the relevance of such indicators is usually very high.

The sections below focus on indicators that reflect the intensity of use of natural resources and the management efficiency of waste and material flows. Indicators reflecting the environmental impacts of materials use are discussed in section 5.5.

5.4.1 Intensity of use of natural resources

Indicators that monitor the intensity of use of natural resources are valuable tools to support sustainable management of natural resources. In its simplest quantitative form, a necessary condition for sustainability can be expressed as the ratio of the growth of a natural resource during a given period over the removal and losses of the resource during the same period. Hence, such indicators generally represent the ratio of natural resource extraction compared to the amount of resources from natural stocks available for use.

The data sources for indicators that reflect the intensity of use of natural resources include:

- Flow relations from **natural resource accounts**
- Physical **asset accounts**
- **Individual MFAcc** and MSA.
- Mining statistics

They do not require the existence of complete material flow accounts.

Resources from renewable natural stocks

When applied to renewable natural resources (biotic resources such as forest resources, agricultural resources, fish resources, wildlife, freshwater resources), such indicators help establish a link between resource abstraction or harvest and environmental concerns related to the reproduction capacity and primary productivity of renewable resource stocks, and to the provision of environmental services. They can further be used to support management decisions in the sectors concerned (e.g. forest resource management, water resource management, fish resource management).

Examples of indicators on the intensity of use of renewable natural resources are included in many international and national environmental indicator sets. They include indicators on the intensity of forest resource use, the intensity of freshwater use, or the intensity of use of fish stocks that can be

derived from natural resource accounts or from material system analysis. Data on timber harvest flows can for example be combined with estimates of sustainable yield in order to identify unused potentials for timber use at sub-national territorial level[42]. The relevant indicator is the "sustainable cut" which needs to be determined by experts for the specific forest resources, and may then be compared with actual use data.

Other useful examples are consistency indicators such as the share of timber imports from sustainable forestry in total timber imports. Such indicators may help assess the impact of timber imports on worldwide forest ecosystems, whether in northern, temperate or tropical areas. Their calculation is however hampered by conceptual and practical difficulties (definition of sustainable forestry, labelling schemes to keep track of trade flows, etc).

Resources from non-renewable natural stocks

When applied to non renewable natural resources, such indicators help establish a link between resource extraction and existing or known reserves that are exploitable under current technological conditions. They can be related to economic concerns related to the scarcity of natural resource stocks, to changes in market prices and to trade flow patterns.

Examples of indicators on the intensity of use of non-renewable natural resources are included in many international and national mining and energy statistics. They include indicators reflecting the apparent life (life index) of the natural resource stock, i.e. total reserves/annual extraction. The apparent life of mine reserves is usually calculated by dividing the total amount of metals remaining in mine reserves at the end of a given year by the corresponding amount of metals contained in the ores produced during that year. Similar calculations are applied at the national level.

Interpretation and limits

The interpretation of indicators on the intensity of use of natural resources must take into account the fact that when applied at national level, they may conceal significant territorial variations within a country. It also needs to take into account the fact that the stocks of some of these resources have an international dimension, that once extracted or harvested many of resources become traded goods (e.g. timber and forest products, agricultural commodities), and that the effects of their exploitation extend beyond the borders of individual countries. Freshwater resources often have a transboundary dimension; fish stocks are not bound to national territories and are monitored by major fishing zone. The interpretation also needs to take into account the role of technology development and innovation.

5.4.2 Management efficiency of waste and materials

Parallel to growing demands for raw materials, the amounts of waste generated have been rising in many countries over the past decades. Thus many valuable material and energy resources are wasted and are lost for the economy. The efficiency with which materials are managed all over their life cycle is therefore crucial for improving resource productivity and preserving environmental quality. This has prompted many countries and business sectors to move from traditional waste management to broader integrated approaches to natural resource and materials management. This is reflected in initiatives such as the 3Rs (reduce, reuse, recycle) or the circular economy that have in common the purpose of closing the material cycle and moving from waste to resources.

Indicators can reflect the management efficiency of waste and material in many ways. In line with the principle of the 3Rs (reduce, reuse, recycle), consistent recycling of used materials helps prevent waste of materials, including energy, and reduce releases to nature. This can be addressed by MF

[42] This has been done, for instance, for a German region north-west of Berlin, Prignitz-Ruppin (Thrän 2003), and a Swiss region (Müller et al. 2004), based on the analysis of wood flows. In the German region only one third of the "sustainable cut" was used, and the rest added to the forestry stock. The analysis provided the basis to determine regional targets for timber product management, e.g. for total timber production, energy wood production, in relation to processing capacities.

indicators that monitor the potential of current material flows for being recycled in future. Such indicators would suggest, which parts of a MF can theoretically be recycled and require a grouping of materials by their level of "recyclability". It can also be addressed by indicators that reflect the level of actual recycling and reuse. Such indicators can be derived from material system analysis and from waste statistics to reveal potentials for recycling.

It has to be noted that recycling and re-use are meaningful operations for many, but not all materials. They are particularly meaningful in the case of metals, constructions minerals, certain other industrial minerals and, to some extent, woody biomass. In the case of metals, most materials are recyclable. Iron and steel scrap for example is being recovered for recycling in many countries or is exported for recycling.

> The data sources for indicators that reflect the management efficiency of material and waste include:
>
> - EW-MFAcc
> - Individual MFAcc and MSA.
> - Life-cycle analysis
> - Waste statistics
>
> There are no readily available data sources for recyclable materials and there is no agreed methodology for measuring this group of materials.

Examples of useful indicators include:

- Indicators reflecting the share of recycled materials (secondary raw materials) in the inputs or the apparent consumption of a given material or a material group, and indicators reflecting the recyclable part of material inputs (DMI_{rec}) or of total material requirements (TMR_{rec}).
- Indicators reflecting the (potential) share of reused goods in material consumption.
- Indicators such as the (potential) use rate of recovered used products (URRUP), the (potential) material use efficiency (MUE), the (potential) material use time (MUT), the (potential) recovery rate of used products (RRUP). (Figure 6, Box 10)
- Indicators reflecting the efficiency of materials use in the primary production and construction branches, such as the ratio of unused domestic extraction over total material inputs (UDE/TMI), or over GDP or gross value added (UDE/GDP or value added in the relevant sectors).

Indicators derived from and associated with LCA-type analysis are being used to indicate the environmental consequences of using primary versus recycled, i.e. secondary materials (with specific pressure indicators) and to determine the conditions under which recycled materials could or should be preferred and whether targets for secondary material input could be developed. Experience remains however limited.

Other examples include indicators that reflect the velocity of material throughput, such as the ratio of Gross additions to Stock (GAS) compared to material consumption (e.g. DMC), including input balancing items. Materials transformed into physical stocks (housing and transport infrastructure, durable and semi-durable goods) remain within the socio-economic system for a comparatively longer period than materials transformed directly into emissions and wastes already during the production phase.

Interpretation and limits

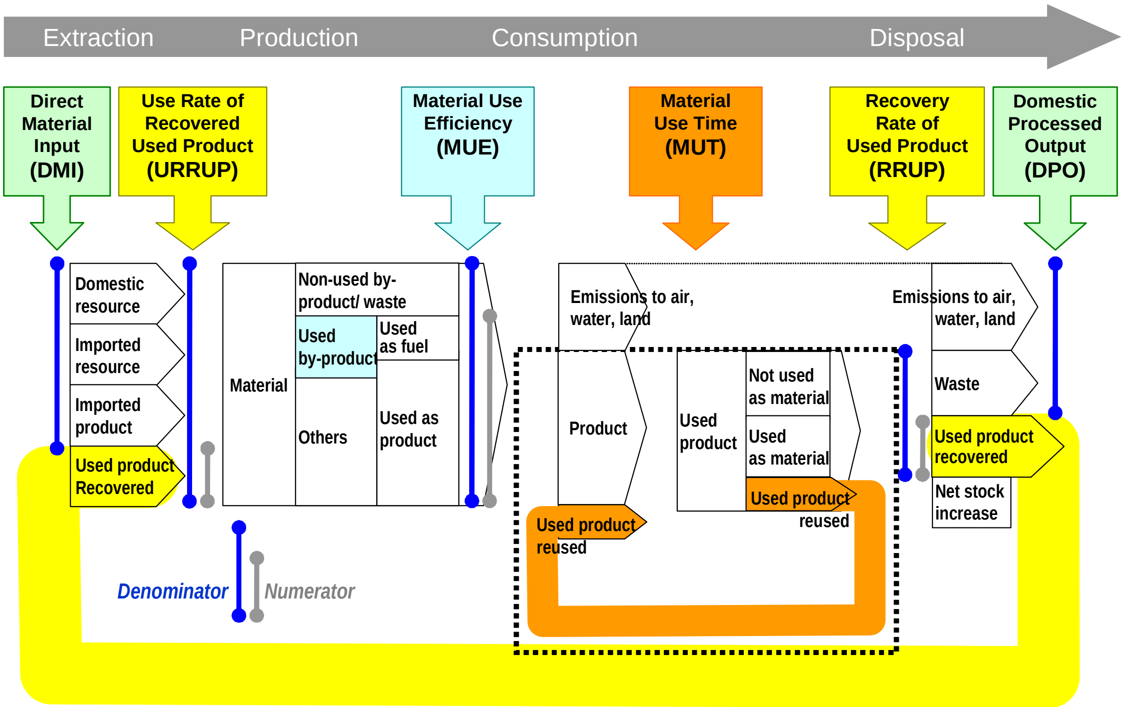
The interpretation of indicators focusing on selected materials or substances is relatively straightforward. The materials tracked are in general closely linked to the problems under scrutiny or linked to particular management issues. From an environmental point of view, their relevance appears to be highest when applied at the meso, micro and local levels.

Some caution has to be exercised in the case of national level indicators. At national level, these indicators may conceal variations among industries within a country. Industrial branches often differ in terms of material throughput, economic development and their technical capacity to reuse and recycle materials. Like most other natural resource indicators, such indicators may hide significant sub-national variations and need to be positioned in the right context. This is especially important when

they are to be used in international work. It is therefore useful to complement the indicators with information on the structure of the economy and to show the proportion of material "intensive" branches versus material "extensive" branches. From an economic and trade point of view, the relevance of material specific indicators appears to be highest at global, macro and meso level, but can also be high at company or plant level.

Such indicators are therefore particularly useful when shown both at national level and by industry. Data availability for indicators by industry is very low. It requires the existence of input-output tables and analysis, which is a resource-intensive effort, or the inclusion of MF variables in regular business surveys.

Figure 6. Material cycle indicators derived from MFA

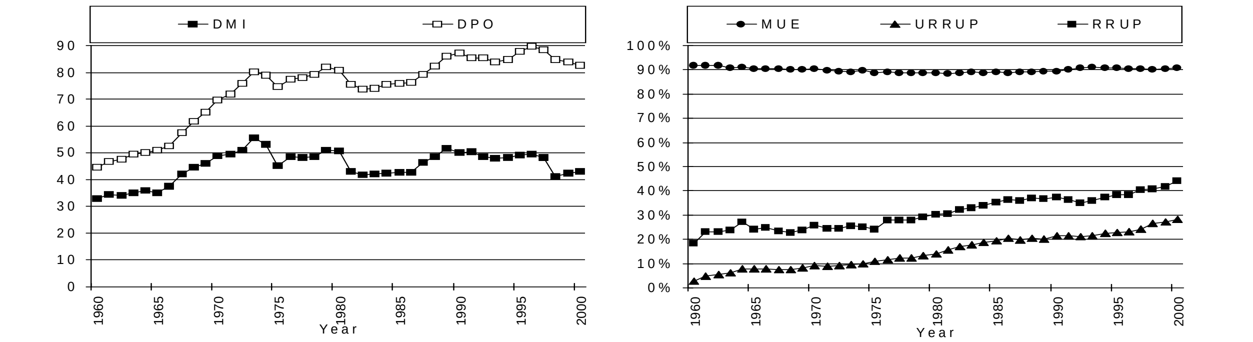


Three material cycles are distinguished, each of them contributing to the objectives of a sound material cycle (i.e. preserving natural resources and minimising the environmental burden):
1-reuse of used products ,
2-recovery of by-products (as material and heat) , and
3-recovery of used products (as material and heat) .

Source: Hashimoto S. and Moriguchi Y. (2004).

Box 10. Monitoring the management of selected materials: Indicator examples

Examples of material cycle indicators for wood resources, Japan



Source: Hashimoto et al. (2004).

5.5. Monitor the environmental impacts of material resource use

Monitoring the environmental impacts from material resource use requires indicators that reflect those characteristics of materials and material flows that have an environmental significance and that are representative of the environmental issues to be addressed.

The use of materials from natural resources has many environmental consequences that often extend beyond the borders of individual countries. These consequences occur at different stages of the resource cycle and affect the quantity and quality of natural resource stocks and the quality of ecosystems and environmental media. The type and intensity of these environmental consequences depend on the kind and amounts of natural resources extracted and materials used, the way these resources are used and managed, and the type of natural environment where they take place.

The sections below give an overview of how the environmental impacts of material use can be characterized and how this can be reflected in the calculation of MF indicators.

5.5.1 Characterising the environmental impacts of material resource use

Measuring the environmental consequences and impacts from materials use and expressing them in the form of indicators is not an easy task.

- First, the term "environmental impact" designates a wide range of effects on the environment that cannot be easily captured in simple numbers.
- Second, many environmental impacts cannot easily be traced back to their origins. Impacts are multi-dimensional; they can be both negative and positive. Impacts vary among the different types of materials; they vary among the different stages of the material flow cycle; they vary among countries, territories, ecosystems.
- Third, the terms "resource use" or "materials use" themselves are often used in a generic way to designate any use of natural resources and materials at any stage of the production and consumption chain.

The selection and definition of indicators reflecting the environmental impacts of material resource use therefore need to build on a good understanding of the way natural resources, materials' use and the related production and consumption processes interact with the environment. It is important to specify the type of impacts to be considered and the audience to be reached, and to define the indicators accordingly. In the case of generic macro-level MF indicators, this helps construct the indicators in a way that enables them to be related to material flow characteristics that are of environmental significance. In the case of issue-specific indicators, it helps identify the materials to be monitored, the appropriate level of detail and the best available data sources.

> The term "**environmental impact**" usually refers to the **direct effect, positive or negative**, of socio-economic activities and natural events on the components of the environment.
>
> It is defined in a broad way and stands for any effect caused by a given activity on the environment including human health and safety, flora, fauna, soil, air, water, climate, landscape and historical monuments or other physical structures or the interaction among these factors; it also includes effects on cultural heritage or socio-economic conditions resulting from alterations to those factors.
>
> It encompasses the pressures exerted on the environment and the resulting changes in environmental conditions.

Environmental impacts of material resource use can be expressed with respect to the pressures exerted on the quantity and quality of the natural resources from which the materials are extracted, and with respect to the pressures associated with the environmental burden (pollution, waste, habitat disruption) generated during the extraction, processing, consumption and disposal of the materials. The main concerns relate to the rate of depletion and the reproduction capacity of natural resources, to changes in environmental services provided by natural resources and to changes in environmental quality (e.g. air, water, soil, biodiversity, landscape, human health).

The extent to which a MF indicator should reflect environmental pressures depends on the purpose for which it is to be used, and on the type of pressure the indicator stands for.

- When an indicator is to reflect a more or less generic pressure, the potential negative environmental impact can be seen as related to the volume or weight of the material flow, and an increase in the indicator's value can be interpreted as a potential increase in the associated environmental impact.
- When an indicator is to reflect a more specific pressure associated with a specific environmental concern (e.g. toxic contamination, human health, biodiversity, climate change), the potential negative environmental impact depends on the chemical or other properties of the materials (Bringezu et al., 2003). Specific pressure indicators therefore need to focus on particular material groups or individual materials, or need to be calculated in a way that reflects the materials' properties and their environmental burden profile. Examples include substance specific indicators derived from SFA and environmentally weighted MF indicators.

Types of materials and material properties

Because materials are not uniform in their physical and chemical properties, their potential for generating negative environmental impacts differs. A first step towards understanding the environmental impacts of resource use and material flows therefore is to distinguish between different types of materials. Commonly a distinction between two broad types is made, toxic flows and bulk flows. (Figure 7).

- The first category, "toxic flows", comprises important industrial raw materials such as industrial minerals (e.g. fertilisers, pesticides), metals (e.g. copper, mercury, aluminium, lead) and fossil fuels used for non-energy purposes (e.g. for the production of plastics, cosmetics).

  The overall magnitude of use of this group of materials is comparatively low in terms of weight, but their potential specific environmental impacts, i.e. the impact per mass unit, can be very high. Many toxic substances further accumulate in environmental media and living species, and present a danger to human and ecosystem health.

- The second category, "bulk flows", comprises non-toxic bulk materials including biomass, construction minerals and fossil fuels. Most of these materials are needed to meet larger socio-economic ends. Agricultural biomass provides food and is gaining importance as an energy source (bio-fuels); biomass from pastures is a major input for livestock; wood is used as a structural material but also as an energy source (fuelwood, charcoal, wood palets). Construction minerals (sand, gravel, stone) supply housing, transport and other infrastructure. Fossil fuels provide energy.

  The overall magnitude of use of this group of materials is high in terms of weight, but their potential specific environmental impacts, i.e. the impact per mass unit, is relatively low compared to that of toxic flows. Since materials unfold environmental pressures at all stages of their lifecycle, the cumulated potential environmental impacts of this group can be very high and often depend on the magnitude of the materials' use.

This very simple distinction between "toxic" and "bulk" flows is sufficient to point at the overall scale of the pressures that the use of materials may exert on the environment. When indicators are to support decision making or policy analysis, the message conveyed needs to be more precise.

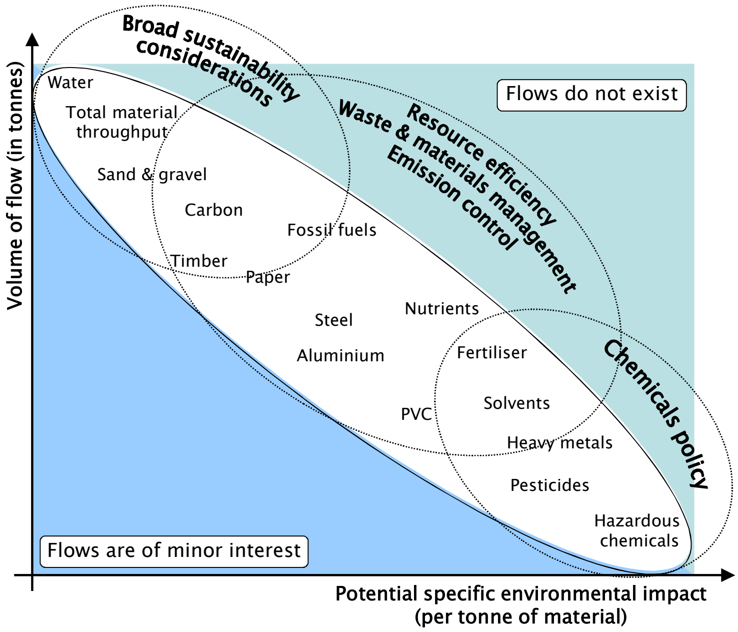
- A breakdown of bulk material flows into food crops, feed crops and timber (for biomass) and oil, gas, coal and others (for fossil fuel carriers) for example is a useful starting point for analysing the underlying drivers and associated impacts, and for identifying potentials for reducing negative environmental impacts.

> - Indicators on "bulk flows" can easily be derived from **EW-MFAcc**.
> - They can usefully be **complemented** with indicators on waste (or pollution) generated by activity sectors such as agriculture, forestry and fisheries, construction, energy production.

- Concerning "toxic flows", the large number of toxic substances ideally necessitates a selection based on risk assessments and quantities of individual substances. Two major types of toxic substances could be considered: heavy metals and organic compounds. Among heavy metals, flows of lead, cadmium, mercury and nickel can be traced. Among organic substances, the flows of certain pesticides can be traced as a first step. It is, however, important to recognise the differences among materials concerning toxicity, persistence and mobility. This raises the question about the relevance of indicators based on mass units only and the feasibility of calculating weighted impact indicators. Currently, no internationally agreed list of substances with appropriate weighting factors exists. Less direct, but more readily measurable indicators are the domestic material consumption, i.e. the apparent consumption, of selected substances or the generation of certain types of hazardous waste that can be used as proxies in the short term.

> - Indicators on "toxic flows" can be derived from **EW-MFAcc**, but their calculation usually requires more detailed information e.g. from **SFA**.
>   Other useful data sources include production, trade and sales statistics for pesticides or fertilisers.
> - They can usefully be **complemented** with indicators reflecting changes in environmental conditions due to toxic contamination (concentration of heavy metals or organic compounds in environmental media or living species), and with response indicators reflecting for example changes of toxic contents in products and production processes.

Figure 7. Schematic representation of material flows, environmental impacts and policy uses



Source: OECD, based on Steurer, A.(1996) as developed with Radermacher W. in 1995.

Table 11. Material groups, environmental impacts, socio-economic ends and policy fields

Material group	Associated potential environmental impact	Socio-economic ends	Related policy fields
Agricultural biomass	Intensification of land use, soil degradation, groundwater contamination, disintegration of nutrient cycles, food chain contamination through pesticides, acidification, loss of biodiversity, habitat loss	Human nutrition, energy provision	Agricultural policy, biodiversity convention
Timber	Intensification of land use, soil erosion, loss of biodiversity, forest degradation, carbon sink depletion, desertification	Structural material, energy provision	Forestry policy, energy policy, biodiversity convention
Biomass from pastures	Intensification of land use, overgrazing, soil degradation, bush encroachment, CH_4 emissions, eutrophication, groundwater contamination, loss of biodiversity, habitat loss	Livestock raising, human nutrition	Agricultural policy
Fish	Overexploitation of natural stocks, biodiversity loss, marine pollution, disintegration of nutrient cycles, habitat loss	Human nutrition	Fishing policy
Metal ores	Scarcity or scarcity of supply, high reactivity, entropy, land use change due to extraction, overburden	Industrial raw material	Industrial policy
Industrial minerals	Scarcity or scarcity of supply, high reactivity, entropy, land use change due to extraction, overburden	Industrial raw material	Industrial policy
Construction minerals	Transport intensity, sealing of land area, soil compaction, loss of biodiversity, carbon emissions in cement industry, land use change due to extraction	Housing and infrastructure, transport	Spatial planning, biodiversity convention
Fossil fuels	Scarcity or scarcity of supply, local emissions, CO_2, global climate change, land use change due to extraction, overburden	Energy provision, industrial raw material	Energy policy, emission policy, Kyoto protocol
Imported semi-manufactured and final goods	Environmental impacts in the country of origin	Intermediary and final consumption	Trade policy

The material flow cycle

A second way to characterise the environmental impacts from material resource use is to distinguish between the different stages of the material flow cycle or the supply chain (Figure 2). This allows to distinguish between pressures exerted:

- During the abstraction stage (upstream), due to movements of used and unused materials, including water, and to pollution and waste generated. The type and intensity of these pressures depend on (i) the rate of extraction or harvest, (ii) the amounts of accessible reserves or available stocks of natural resources, and (iv) the management practices and the technologies applied. (section 5.4.1).
- During the processing and consumption stages (downstream), due to pollution and waste generated (process related, accidental). The type and intensity of these pressures mainly depend on the management practices and the technologies applied, on the level of compliance and enforcement with government policies, and on consumer behaviour.
- During the waste treatment and recycling stages (post-consumption stages) where the type and intensity of the pressures again depend on the management practices and the technologies applied, and on the level of compliance and enforcement with government policies.
- During the transportation stages, directly via transport accidents or leakages, such as oil spills, and indirectly via energy consumption and related air emissions. The type and intensity of these pressures mainly depend on (i) the mode of transport, (ii) the safety rules applied, and (iii) the level of compliance and enforcement with international agreements such as those on the transport of hazardous goods, the prevention of marine pollution or the transboundary movements of hazardous waste.

- Indicators reflecting environmental pressures during the **abstraction stage** can be derived from various types of material flow accounts, including economy-wide MFAcc, individual MFAcc and MSA, and from natural resource accounts (flow accounts and asset accounts).

  Other useful data sources include mining statistics and geological surveys.
- Indicators reflecting environmental pressures during the **processing and consumption stages** can be derived from all types of material flow accounts: economy-wide accounts, individual material flow accounts, PIOTs, etc..

  An exception are indicators reflecting accidental releases of pollution. They have to be based on other data sources (e.g. insurance records).
- Indicators reflecting environmental pressures during the **transportation stages** cannot be derived from material flow accounting. Their calculation has to be based on other data sources (insurance records, convention secretariats, waste statistics, etc.).

One can also consider pressures and impacts from the whole process chain. This reflects the fact that, whether toxic or not, most materials unfold environmental pressures at all stages of their life cycle, from extraction, to transformation, use and disposal, via transport. The cumulated effects on the environment from these pressures may be high, but are difficult to capture in the form of indicators. Aggregated economy-wide material flow indicators have been used as proxies to reflect this cumulated pressure from overall materials use. Indicators derived from life-cycle analysis or from substance flow analysis have been used to reflect this cumulated pressure for particular products or substances. Efforts are being made to develop environmentally weighted MF indicators.

Internal and external impacts

A third way to characterise the environmental impacts from material resource use is to distinguish between internal and external impacts, i.e. between impacts that occur within the borders of a country at the place of extraction, processing, use and disposal of materials, and impacts that occur outside the borders of a country, upstream in the production process and that are indirectly associated with imported materials and products.

This distinction helps monitor shifts in the location of potential environmental impacts due to changes in domestic material demands and consumption, to changes in related trade patterns and to foreign outsourcing.

Examples of generic indicators that reflect internal versus external impacts include output indicators such as: domestic processed outputs (DPO), total domestic output (TDO) and indirect flows associated with imports (IF_{IMP}). To give insights into shifts in the location of potential environmental impacts abroad, the indicators need to be complemented with information on import flows by country or region of origin.

- Indicators reflecting internal versus external impacts can be derived from economy-wide MF accounts, as well as from individual MF accounts and material system analysis.
- Data on unused and indirect material flows associated with the extraction and import of materials are however not yet sufficiently developed and require further work on conversion factors and calculation methods.

The interpretation of such indicators needs to consider that, though the environmental consequences of materials use frequently extend beyond the borders of individual countries, the actual impacts and the environmental problems associated with the extraction, processing, use and disposal of materials, (e.g. on air quality, water quality, biodiversity, human health) are often localised in nature, and their type and severity depends on many factors, including meteorological and climatic factors, geological and hydrological factors, etc. As a result, the environmental implications of using specific materials and technologies frequently vary from country to country, and even from site to site.

Intentional versus unintentional releases to the environment

A distinction can also be made between pressures exerted by materials whose release to the environment is intentional and materials whose release to the environment is unintentional. A majority of materials released to the environment are unwanted by-products of production and consumption processes, which are discharged to or disposed on the environment domestically or abroad (waste that is landfilled, pollutant emissions to air, water, soil). These flows generate environmental pressures, but rarely produce any benefits. Other materials are released to the environment on purpose (e.g. mineral fertilizers or pesticides) as part of an economic activity, and the benefits related to their use usually outweigh associated negative environmental impacts.

Examples of indicators that reflect intentional versus unintentional releases of materials to the environment include: the share of emissions and waste generated in the domestic processed output (DPOem/DPO) and share of dissipative uses of materials in the domestic processed output (DPOdiss/DPO).

- Indicators reflecting intentional versus unintentional releases to the environment can be derived from economy-wide MF accounts, as well as from individual MF accounts and material system analysis.

5.5.2 Linking macro-level MF indicators to environmental impacts

From an environmental point of view, MF indicators – whether they reflect material inputs, material consumption or material outputs – inform about anthropogenic, i.e. man-made pressures on the environment. They inform about the direct or proximate environmental pressures that are associated with:

- The extraction of resources. These indicators complement other natural resource indicators, such as those describing the intensity of use of water or forest resources, or those describing energy intensities and efficiencies. They relate to issues concerning the environment's "resource function" (OECD, 1993) and can be associated with natural resource management policies and approaches. The most commonly used material extraction indicator is domestic extraction used (DEU). DEU gives a partial overview of the environmental pressure of materials extraction and needs to be complemented with information on the unused domestic extraction (UDE).

  N.B. The extraction of raw materials from natural resources is not always environmentally significant in its own right, but is useful to track changes in the quantities and value of materials produced against future declines and to provide some insight into the scale of the pressure of extraction. It has been used to provide insights into the cumulative burden associated to MF of production and consumption.

- The discharge of pollutants and waste materials. This is the case of indicators that reflect the outputs of residual materials to nature. These indicators complement other environmental indicators describing pollution or waste generation intensities. They are closely related to the environment's "sink capacity" and to environmental quality issues, such as biodiversity, toxic contamination, waste, air quality, climate change. (OECD, 1993). The advantage of output indicators derived from MFAcc is that they help relate material inputs into an economy or an activity to its material outputs and to calculate coherent pollution and waste intensity ratios.

MF indicators also inform about the indirect or underlying activities or factors that cause direct environmental pressures and that are associated with the use and the accumulation of materials in the economy. This is the case of indicators that reflect material inputs and consumption and related intensities, and of indicators that describe material stocks and the physical trade balance of an economy. Materials accumulate in the economy in the form of housing and transport infrastructure, or in the form of durable and semi-durable goods. These materials are sooner or later released back to the environment in the form of demolition waste, end-of-life vehicles, e-waste, bulky household waste, etc..

> Environmental pressures describe pressures from human activities exerted on the environment, including natural resources. “Pressures” cover underlying or indirect pressures (i.e. human activities themselves and trends and patterns of environmental significance, often referred to as "drivers") as well as proximate or direct pressures (i.e. the use of resources and the discharge of pollutants and waste materials).
>
> Indicators of environmental pressures are closely related to production and consumption patterns; they often reflect emission or resource use intensities, along with related trends and changes over a given period. They can be used to show progress in decoupling economic activities from related environmental pressures, or in meeting national objectives and international commitments. (OECD, 1993, 2003)

Generic EW-MF indicators are however not sufficient to reflect issue-specific environmental impacts. Research to develop material flow indicators that more closely relate to actual environmental impacts, and hence to well recognised environmental policy concerns is in progress.

It can be done by using indicators that focus on flows raising specific environmental concerns individually or as a group with respect to air pollution, loss of biodiversity, toxic contamination, human health, climate change, etc. At the very detailed level, when MF indicators focus on specific hazardous substances and are applied at the micro level, these relationships are easier to establish. At these levels there is a closer link between the weight of the flow and its potential environmental impact. MF data can also be related to results from local environmental monitoring networks and associated with SFA, and can add value to other information tools, e.g. pollutant release and transfer registers.

> Depending on the approach taken, and the primary interest of the study, the data input needed to calculate macro-level indicators reflecting environmental impacts can come from material flow or substance flow accounting, used together with other tools. Examples are:
>
> - Economy-wide MF accounts, associated with LCA
> - Individual MF accounts and material system analysis, associated with LCA
> - Substance flow accounts and analysis
> - Environmental monitoring data
> - Pollutant Release and Transfer Registers (PRTRs) and emission inventories
>
> In the case of indices that weigh materials according to their environmental impact, a combination of data sources and types of analysis is required.

Reflecting the environmental burden of materials use can also be done by aggregating materials by common characteristics so as to reflect their environmental burden profile or by weighing selected materials or substances according to their potential environmental impact or toxicity.

- Indicators derived from and associated with material system analysis, e.g. on iron & steel, can show, which processes from extraction to final disposal are associated with the highest resource inputs on the one hand, and the highest waste and pollutant releases to the environment on the other hand. They are particularly useful when the issue of concern is environmental hot-spots of the processing network and can be used in combination with impact indicators derived from life cycle analysis (LCA). (Box 11)

- Indicators reflecting the environmentally weighted material consumption can be used to inform about the overall environmental burden arising from the use of selected materials (see below);

- Indicators derived from and associated with SFA can show which processes are associated with the highest losses of hazardous substances to the environment (when the flow of the critical substance is the indicator), and hence be used to support pollution prevention and control policies, chemicals management and the control of toxic substances. They are particularly relevant when the issue of concern is toxic contamination and when applied at the local or micro level, but can also be applied at a larger scale. (Box 11, Box 12)

Environmentally weighted MF indicators

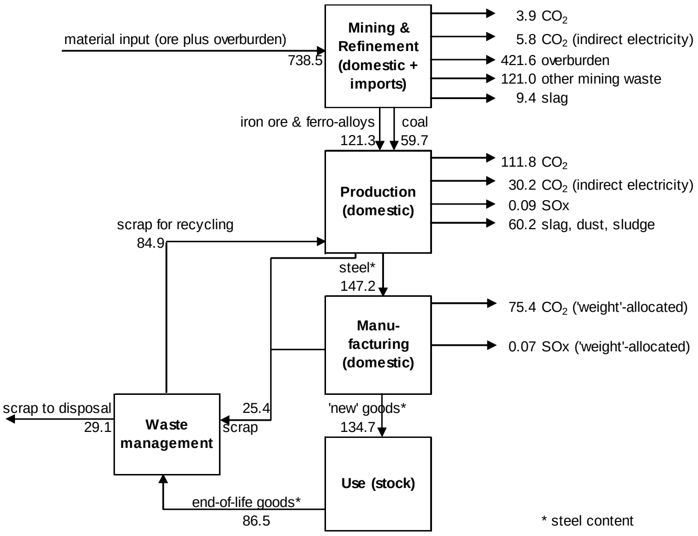
There have been a few attempts to weight material flows according to their environmental impacts. The impact-based weights might distinguish between large flows with little impact per unit of flow (inert or bulk materials) and small flows having large impacts per unit of flow (highly toxic or persistent materials)[43]. A recent example is environmentally weighted material consumption (EMC) that combines data from material flow analysis (MFA) and impact coefficients from life cycle analysis (LCA). EMC has been calculated for a group of European countries and for the Netherlands. (Box 13).

Work in this area is progressing, but there are still problems of data availability and weighing methods that constrain a systematic development of such indicators at the international level. Developing environmentally weighted measures of materials flows requires a consensus about the validity of the conversion factors used, about the criteria to be used to select the materials to be covered and about the weights to be allocated to each material and to each impact group. This is not an easy task, but can be more easily achieved within a country, in particular at local level, than at international level. The narrower the geographic scope, the greater the homogeneity in spatial and environmental characteristics, and the easier the interpretation of the indicators. Weighted MF indicators appear therefore to be more useful when applied at the national or the local level, or when applied to a homogenous group of countries for which they can give a representative picture. Work towards developing recommended impact coefficients and assessment methods is proceeding within the European Union (http://lca.jrc.ec.europa.eu), and is promoted by the UNEP/SETAC Life Cycle Initiative (http://www.unep.fr/scp , http://www.setac.org/).

43 Suggestions on how to weight material outflows were presented for example by Fröhlich et al. (2000) and Matthews et al. (2000).

Box 11. Monitoring the environmental impacts of materials: Indicator examples (1)

Overview of the "environmental hot-spots" of the iron & steel system, European Union, 2000 (million tonnes)



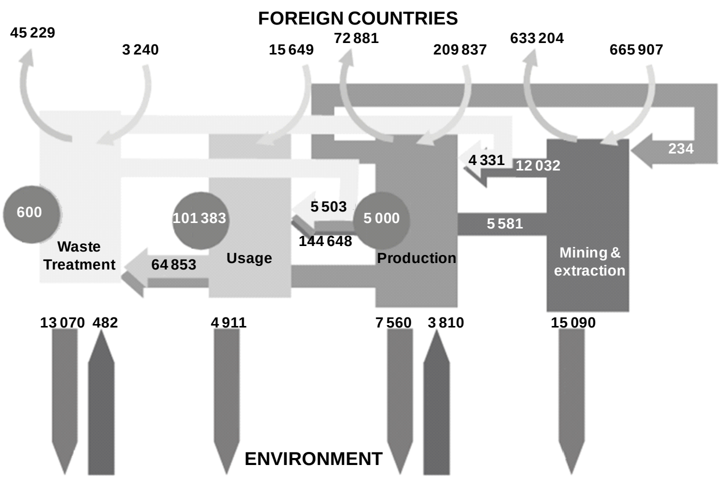
In this example, the iron and steel system of the EU was analysed on a life-cycle wide basis to address the "environmental hot-spots" along the production-consumption chains.

The figure presents the resulting indicators reflecting major resource inflows, critical emissions and recycling of the extended process network.

The study showed that the environmental pressures of primary steel exceed those of secondary steel significantly (ore vs. scrap based supply). The analysis, however, revealed that, even complete recycling (i.e. 100% of the currently generated scrap) would not fulfill current demand for steel and that scrap levels will not meet the level of iron & steel demand before 25 years in the future (an insight that would not have been reached without a MFA model). The results suggested technology improvements and indicated the need for higher materials efficiency in the sectors that use iron& steel as a base material (e.g. construction and automotive sectors).

Source: Moll et al. 2005

Data from substance flow analysis, the Netherlands



This example builds on results from a substance flow analysis (SFA) carried out to detect those processes that are most involved in the release of harmful substances to the environment.

The study showed that releases of cadmium stem from diffuse applications that may lead to an exceedance of critical levels in the environment. Here, the flow of the critical substance, i.e. cadmium, becomes the indicator itself.

The analysis led to the insight that emission control and even product bans will not solve the problem. Since inflow always equals outflow the authors conclude that the only way to reduce the outflow to the environment is the reduce the inflow to society. Cadmium, however, is produced not on demand but as a by-product of the zinc industry. The only real solution to this problem would thus be to either reduce the amount of zinc being produced or to immobilise the cadmium directly after production.

Source: Kleijn and Voet, in OECD 2003

Direct and indirect environmental pressures by product groups delivered to final demand, late 1990s, Germany

	Resource inputs							Induced environmental burden				
		Total material requirements									Waste	
Product group	Primary energy supply	Fossil fuels	Metals	Industrial & constr. minerals	Biomass	Land-use: built-up area		Global warming potential	Potential acidifying effect	Tropospheric ozone formation potential TOFP	Without bulky C&D waste	Bulky C&D waste
Construction	7%	7%		33%		9%		7%	5%	5%	9%	61%
Food products	6%	4%			36%	17%		9%	25%	5%	12%	
Motor vehicles	9%	6%	23%	7%				8%	5%	5%	7%	
Electricity & gas	10%	19%						16%	7%	4%	8%	
Basic metals	4%	5%	28%	12%				4%			8%	
Products from agriculture, hunting, etc.					19%	13%		4%	16%			
Chemical products	12%	7%						5%	4%	4%		
Machinery & equipment	5%	3%	12%					4%			5%	

In this example, the direct and indirect environmental pressures from resource use (primary energy, primary material, land use) and the specific emissions and waste were attributed via input-output analysis (IOA) to the branches, which deliver products to final demand. The table records the share of the pressures induced by branch in a NAMEA type fashion. It shows that the sectors that contribute significantly to pollution and waste also require a high share of resource inputs. This has been interpreted in a way that resource efficiency strategies might be synergistic with efforts to mitigate climate change, pollution control, waste prevention and resource conservation.

Source: Moll et al., 2003

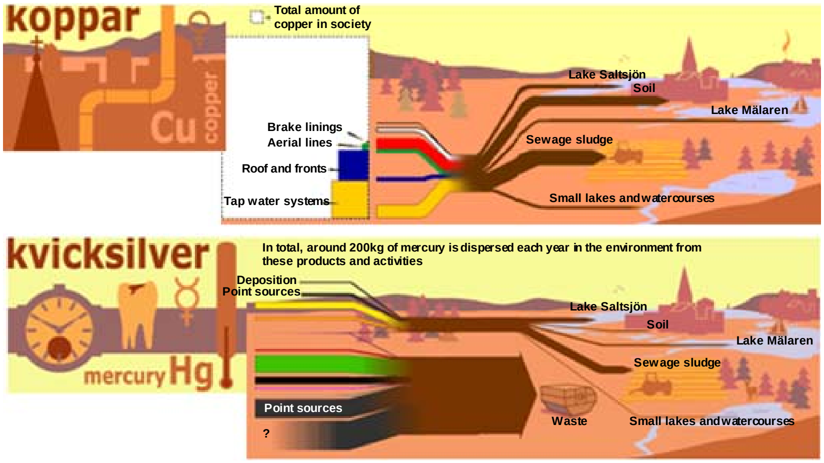
Box 12. Monitoring the environmental impacts of materials: Indicator examples (2)

Heavy metal flows in Stockholm, Sweden

This example builds on results from a series of substance flow analysis (SFA) used to support the Stockholm city's environmental programme and related public communication.

It is part of a web presentation that shows where toxic substances released to the environment originate from (copper, lead, mercury, cadmium, PAH-polyaromatic hydrocarbons). Main sources are diffuse emissions from the use of products, not industrial sources.

For each substance, the presentation informs about its characteristics, the products in which it is contained, the way it disperses and impacts on the environment, and the measures that can be taken and by whom to reduce negative environmental impacts.



The information is presented at different levels of detail to suit different users. Main target groups are students (from about age 13 and elder), politicians, and civil servants.

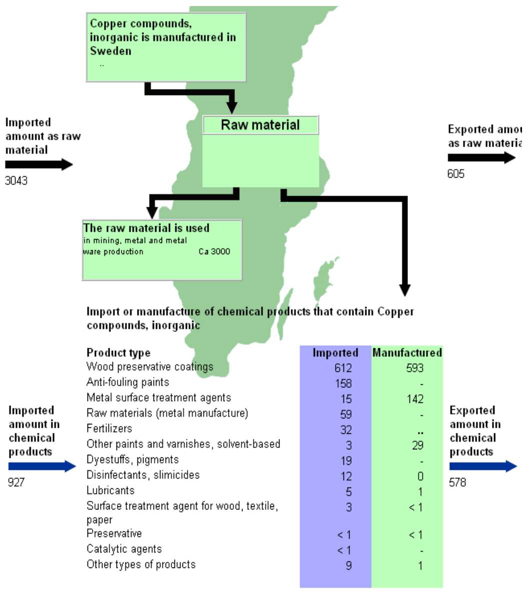
Source: Stockholm city, www.stockholm.se/miljogift.

Copper flow chart, 2004, Sweden

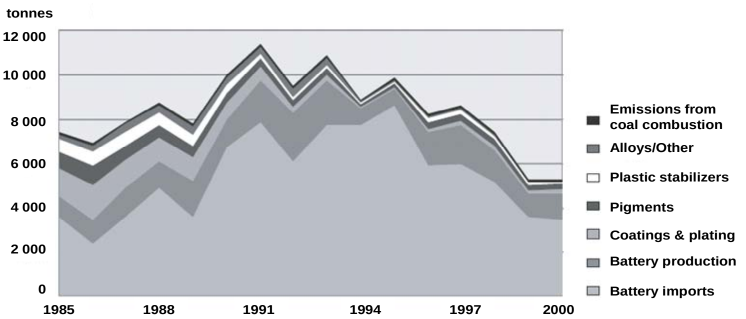
This example is part of a series of flow charts for chemical substances made publicly available by the Swedish Chemical Agency.

The data are retrieved from the Products Register.

Source: Swedish Chemicals Agency



Estimated Cadmium Releases by end-use products, United States, 1985–2000



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

Source: WRI Material Resource project. Extract from Material Flows Accounts – A Tool for Making Environmental Policy, Wernick and Irwin, WRI, 2005

Box 13. Environmentally weighted material consumption

Environmentally weighted material flow indicators are being developed to increase the relevance of MF indicators for environmental policies by integrating information about the environmental impacts associated with materials extraction and use in the calculation of the indicator.

Method

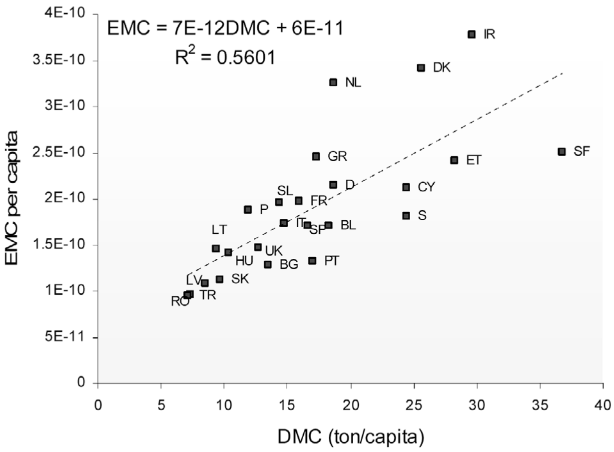
The calculation of environmentally weighted material consumption (EMC) builds on data from economy-wide material flow accounts (EW-MFAcc) combined with information from life cycle analysis (LCA). It is based on the apparent consumption (domestic production plus imports minus exports) of selected base materials whose mass is multiplied with LCA impact coefficients.

EMC shows overall potential environmental impacts of material consumption in a country, wherever and whenever these impacts may occur (on the domestic territory or abroad, now or in future). It does not reflect actual impacts occurring in a given country in a given year.

Impact categories

In life cycle assessment (LCA), the development of a common framework for environmental impact assessment has led to the identification of the most relevant environmental impact categories and corresponding indicators. The impact categories consider impacts on natural resources, on ecosystem quality and on human health. They comprise the extraction of biotic and abiotic resources and land use on the input side, and a number of impact areas on the output side, including climate change, human toxicity, eco-toxicity, acidification, eutrophication.

Impact weighted material consumption in European countries (EU-25 + ACC-3)



In this example the EMC index is based on the apparent consumption of 31 selected base materials. Each material was attributed its life-cycle wide environmental impacts based on LCA coefficients covering 13 impact categories. The shares of each country are normalized against the global impact of each equally weighted impact category.

Although there is some variation between countries, especially at higher values, the EMC correlates with the Domestic Material Consumption (DMC) indicator at national level. However, as the authors explain, "this probably implies that the composition of material consumption does not differ that much across countries, which are to a certain extent comparable in terms of market structure and which have extensive trade with each other".

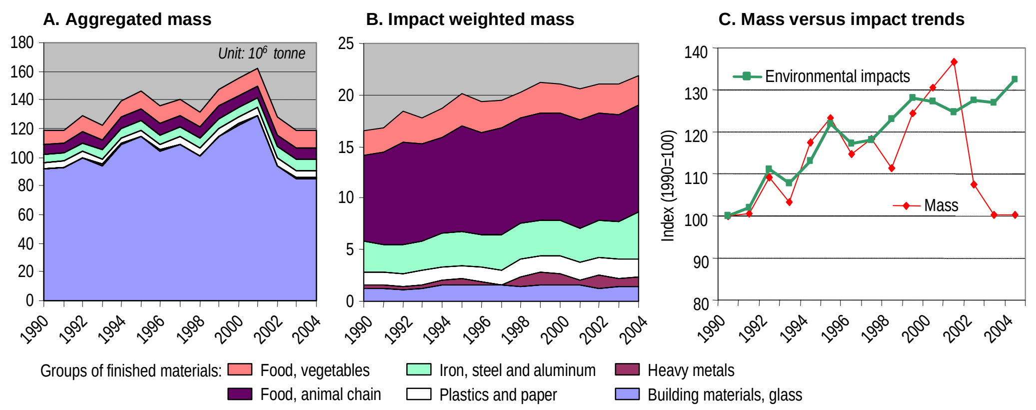
This result may also be influenced by the fact that indirect flows of imports are not considered in DMC and that DMC does not link to actual environmental impacts.

Source: Voet et al. 2005

Impact weighted material consumption in the Netherlands

- Total environmental impact (TEI)= Mass of material consumption (finished materials) x impact coefficient (constant)
- Selection of 21 material groups with highest TEI (ca. 90% of total) excluding direct energy use
- Weighting the 11 LCA impact categories (choices: implicit, economic or panel)

Domestic material consumption in the Netherlands, 1990-2004



Source: de Bruyn, S., OECD Rome workshop, 2006..

6. USING MATERIAL FLOW INDICATORS[44]

Several countries and international organisations have included MF indicators in their sets of environmental or sustainable development indicators. Most of these indicators make use of data from economy-wide MF accounting, a few make use of data from substance flow analysis or from physical input-output tables. Experience exists with using MF indicators to support certain aspects of environmental policies and sustainable development strategies, the focus being on waste and materials management. MF indicators and other information from MF studies have also been used to monitor toxic contamination and inform about health related issues. Experience with using them in other policy areas is more limited.

Debates about the interpretability of MF indicators and their relevance for particular environmental and economic policies have shown that users are not always familiar with these indicators, their meaning and their limits, and that the respective roles of the indicators and of the underlying statistics are not always well understood. This has led to over-interpretation and misuse of some of the indicators released to the public, in particular those that are highly aggregated.

6.1. Guiding principles

It is important to be pragmatic when using MF indicators. The ideal indicator, meeting all the selection criteria described above, does not exist. Indicators always result from trade-offs between the analytical soundness and robustness of the measurement tools chosen, the practicality of their implementation and their particular relevance for countries or for international work.

To make most effective use of the indicators it is therefore helpful to keep in mind the following general principles that the OECD applies when using environmental indicators in policy analysis and evaluation:

1. **Indicators are only one tool; they are not a substitute for analysis and evaluation.**

   MF indicators are not intended to tell the whole truth nor to provide a mechanical measure of the sustainability of material resource use or of the performance of related policies and measures. They are rather intended to highlight the interface between resource use patterns, and economic and environmental issues, and to describe the path towards improved resource productivity. They have the purpose to attract attention to situations or trends that require further analysis and subsequent action, and hence help orient the focus of in-depth studies.

2. **Indicators need to be interpreted in context**

   Indicators have the advantage of being concise and having a meaning that goes beyond the simple parameter value. However, there is a danger of misinterpretation if they are presented out of context and without appropriate information about their significance and limits. To acquire their full meaning, the indicators must be reported and interpreted in context, taking into account the ecological, geographical, social, economic and structural features of countries.

3. **Cross-country comparisons and standardisation**

   When used in international work, some standardisation or normalisation is usually needed to facilitate cross-country comparisons. There is however no unique method of normalisation for comparing indicators across countries. The outcome of the comparison will depend on the

[44] Based on guidance developed for using environmental indicators in environmental country reviews (OECD, 1993, 2003a)

chosen denominator (e.g. GDP, population size, land area). It is therefore appropriate for different denominators to be used in parallel to balance the message conveyed. In some cases, absolute values may be the appropriate measure. This is the case when, for example, the indicator tracks progress towards a quantitative target based on a reference value expressed in absolute terms.

Having these general principles in mind helps avoid over-interpretation and misuse of the indicators.

Beside these general principles, each type of indicator can benefit from more specific guidance and recommendations on how best to use and interpret them. Such guidance has to take into account the main purpose and audience of the indicators and their level of application, their main advantages and drawbacks, and the factors having a bearing on their relevance.

6.2. Factors having a bearing on the relevance of MF indicators

A number of factors have a bearing on the policy relevance and usefulness of MF indicators. Among these are methodological and measurement issues, including data quality and availability, and country specific factors. Other factors that play a role, especially for national level MF indicators, are the level of aggregation of the indicators, and the way they can be related to environmental issues, to economic demand and supply issues, and to globalisation and trade issues.

Being aware of these factors and understanding how they interact is important to guide the selection, interpretation and proper use of the indicators, and to identify those issues and policy areas to which the they contribute best. It is particularly important in the case of economy-wide MF indicators that suffer from a lack of credibility, with debates focusing more on their analytical soundness than on the measured values and their significance.

Measurement issues

Measurement issues such as the quality of underlying data are important in the use of any MF indicator, and must be taken into account to avoid misinterpretation. Measurability and data quality vary among individual MF indicators. Some indicators are easily measurable and of good quality, others need additional efforts before they can be published and used.

Data availability and quality is generally best for indicators describing direct flows and for indicators based on input and consumption variables. (material extraction, imports, exports). The data underlying these indicators are readily available from known sources, and can easily be updated at regular intervals.

Output variables are less well covered, and related indicators are still in development both from a methodological point of view and in terms of data availability. Data needed to populate the output side of material flow accounts are available from waste statistics, emission inventories and other environmental statistics. But a number of gaps remain, and the use of these data for accounting purposes often requires a restructuring and adaptation to accounting definitions and classifications. Gaps also remain in the coverage of international flows of resources and materials and in the coverage of unused or indirect flows. Little coherent information is available on flows of secondary raw materials (recycled materials). Almost no information is available on recyclable materials. The development of related indicators requires further work on definitions, methodologies and conversion factors, and an international consensus about the validity of these methodologies.

Timeliness	An important criterion affecting the relevance and usefulness of an indicator is the timeliness of the underlying data. The interval between the period to which data refer and the date when data are released should be as short as is practicable. Timeliness of data from environmental accounting is often insufficient for policy evaluation or for public communication purposes. Unlike some economic data, such data often lag behind referring to up to five years prior to the current year. For indicators monitoring trends or structural changes over longer periods (i.e. 20 years or more), timeliness is not a major criteria. For indicators that inform about the results of policies and measures and that are to be used to guide decision making and evaluate performance, timeliness is essential and should be the same as for major economic indicators.
Coherence over time	The availability of coherent data over longer periods is essential to keep track of the effects of earlier policy measures and to monitor changes over time. It is particularly important for indicators that are designed to reflect structural changes over time, changes in productivity levels and changes in the origin or the destination of material flows within a country or at global level. To be meaningful, most indicators on material flows and resource productivity require a systematic presentation of trends over longer periods. When used in international work, a comparison of trends expressed as index values may even be more meaningful than a comparison of status variables expressed in absolute or relative terms.
Coherence among and within countries	Because of the globalisation of international markets, and the interdependency of material flows among countries and world regions, MF related issues are important at both the national level and the international level. To make MF indicators meaningful for decision making and performance evaluation, it is therefore important that a minimum of coherence among countries is ensured, that the underlying concepts, frameworks and methods are applied in a harmonised way in all countries, and that there is a consensus about their validity among the countries concerned. Coherence among countries is essential to ensure their international comparability and to ensure that the messages they convey are credible and relevant for international work. Coherence within countries is important when MF indicators are used in conjunction with an analysis of structural changes in the economy or with an analysis of the environmental impacts of materials use that are often localised.
Coherence with national accounts aggregates	The unit in which GDP is expressed can influence the message conveyed by productivity or decoupling indicators. For time series recording development of GDP, constant prices should be chosen, and comparisons of countries with varying economic development patterns for a given year should preferably relate to GDP measured on the basis of purchasing power parities (PPP)[45].

Country specific factors

As OECD countries show big variations in their geographical and socio-economic context and their endowment in natural resources, the relevance of different MF indicators and of the messages they convey necessarily vary among countries. To make the indicators work operational in the practical setting of governments' policies, it is important to know the extent to which country-specific factors affect the values of different types of indicators and how this affects the interpretation of the indicators and their international comparability.

Among the country-specific factors that need to be considered are growth factors, structural factors, technological factors and climatic factors:

- The scale and growth of the national economy, its structure and the characteristics of its industrial basis (structure: primary industries versus manufacturing and construction and services)

45 Moll, S., Bringezu, S. (2005): Aggregated indicators for resource use and resource productivity. Working Paper, ETC-WMF, Copenhagen

- The country's endowment in natural resources
- Trade patterns, including import penetration and the degree of dependence on external markets, competitiveness and level of integration in the world market.
- The level of technology development and uptake: changes in the technologies of production and use of products are a determinant of the environmental consequences of economic growth and of resource productivity.
- Geographic and climatic factors that have a bearing on the interpretation of environmental impact indicators and of indicators on the intensity of use of natural resources.
- Socio-demographic patterns and trends (e.g. population density and growth), lifestyles and consumer behaviour.
- Factors related to institutional arrangements and to governance principles that have a bearing on the interpretation of resource productivity and material dependency indicators.
- Government policies, policy instruments and measures.

Many of these factors have a clear bearing on the significance of MF indicators that do not cover "hidden" flows, such as DMI and DMC. Decreases in the amounts of direct material inputs for example can be due to factors such as the closure of old plants, the uptake of new technologies, or the contraction of certain industry sectors. These indicators therefore sometimes convey similar messages as structural economic indicators, their value added lying in their capacity to being related to "hidden" flows and to environmentally relevant material outputs in a coherent way.

Among other factors that are important, though not country-specific, are raw material prices and changes in real terms that have a bearing on material productivity and efficiency indicators.

Information about these factors has to be made available to the users of the indicators so as to facilitate the interpretation of the indicators, and to explain variations among countries when used in international work.

A study on international comparisons of resource use showed that one third of the differences in DMI per capita can be explained by differences in GDP[46]. At the same time two thirds of the variations was determined by country specific influences:

- Population density may inversely influence per capita use of materials because, e.g. in sparsely populated countries longer transport ways per person are built with higher amounts of construction minerals than in more densely populated countries.
- Other basic conditions such as climate which determines the need for cooling and heating, may have some influence although usually not in an overriding manner.
- The influence of other parameters like economic structure and investment behaviour can usually only be determined by multiple correlation analysis, and research towards this end is ongoing. One interim result is that many countries have their own material resource mix, which may be the consequence of special endowment in certain natural resources (e.g. forest products in Finland) or certain historical developments of technology (e.g. use of oil shale in Estonia). A high reliance on the primary sector (e.g. in the USA) may also exert its influence like cultural traditions of consumption (e.g. fishery based food sector in Japan).

[46] Bringezu, S. et al. 2004: International comparison of resource use and its relation to economic growth. The development of total material requirement, direct material inputs and hidden flows and the structure of TMR. *Ecological Economics*, 51(1-2): 97-124

Level of aggregation

The choice of an appropriate level of aggregation, well adapted to the use of the indicators and their audience is crucial. In general, a balance needs to be struck between the wish to have as few indicators as possible and the need to keep each as intelligible, robust and transparent as possible.

The higher the level of aggregation, the greater the need to embed the indicators in a solid information basis that enables subsequent analysis and a coherent documentation of the indicators, and to position them in a broader set of indicators.

6.3. Enhancing the information value of MF indicators

The way the indicators are defined, calculated and expressed influences their information value and hence their relevance and utility for users. Each of the listed basic MF indicators helps answering different types of questions (Table 1). Each indicator has its own definition, is based on certain system assumptions and results from a certain level of simplification or aggregation of the original data sets.

Relating indicators to reference values

Interpretability can be enhanced by the use of reference values such as benchmarks, thresholds, baselines, goals or targets. Comparing indicators to reference values helps users better understand the significance of the indicator values, and enables comparisons between data that are otherwise not easy to compare.

A reference value might be a qualitative objective (aim, goal), a target (distance to target), a baseline (distance to a certain state), a threshold value (distance to a collapse), a reference year (change in time) or a benchmark (difference with another country or entity).

The choice of the reference values depends on the purpose for which the indicators are to be used. Indicators can often be related to more than one reference value. Reference values can also change over time as scientific knowledge progresses, or as a result of national or international negotiations. Reference values are therefore usually not part of the indicator's definition or methodology. This would limit the indicator's usefulness and its further development or adaptation to specific contexts.

General reference values and benchmarking

The reference values to which MF indicators are related, are often goals or aims, i.e. broad qualitative objectives, including for example calls for "reduced consumption of non-renewable natural resources with focus on minerals, metals and fossil fuels" (EC, 2003) or for "reversing the loss of environmental resources" (UN, 2001).

The assessment then consists in using the indicators for benchmarking and complement them by a trend analysis (tracking changes in the values of indicators over time).

Quantitative targets

Quantitative targets to which MF indicators can be related to, have been used more rarely, but are promoted by a number of countries. Such targets state for example that "resource productivity will improve by 40 % by 2010 compared to the baseline year 2000" (Government of Japan, 2003), or that "the objective must be "to increase the productivity of resources by a factor of 4" (Austria, SDS), or "reduce TMR: -25% by 2010; -75% by 2030; - 90% by 2050"(Italy, SDS).

Quantitative targets can be defined on the basis of scientific theory and research, but in practice they usually arise from political consensus building processes of selection and negotiation. The two approaches are often complementary.

In the absence of a consensus for many of the environmental goals concerning material efficiency, the targets are often just based on existing scientific analyses of both what seems to be needed and what seems to be feasible within a given time frame. Related indicators then are more descriptive in nature. They contribute to informed decision making, but are less useful for performance evaluation.

Links and synergies with other indicators

MF indicators are particularly meaningful when positioned in the broader context of material flow analysis and when associated with other relevant indicators (environmental indicators, selected socio-economic indicators, sustainability indicators, etc.). This provides complementary or contextual information, helps see the interrelationships between different types of indicators, and identify those that are most relevant for a given purpose.

In order to get a better understanding of the reasons for the differences between countries, the values of basic MF and RP indicators need to be supplemented by other indicators and more detailed information. Sometimes the use in parallel of absolute values and efficiency indicators, as well as of different denominators or numerators is recommended.

Single indicators rarely give a representative picture of a situation. Though capturing easily the newspaper headlines and the attention of the general public, a single indicator can also easily be misused. It is therefore recommended to integrate MF indicators in existing sets of environmental or sustainable development indicators, or to develop a balanced set of MF indicators.

Links with other natural resource indicators	Many MF indicators are by definition closely related to other indicators derived from natural resource accounting, such as those relating to water resources or forest resources or those describing energy intensities and efficiencies. The complementarities and synergies with these other natural resource indicators can be used to put MF indicators into the broader context of natural resource use and management. Similar synergies can be exploited with environmental indicators describing pollution or waste intensities.
Links with economic indicators	Indicators that reflect the efficiency of the use of natural resources and materials, are by definition closely relates to other productivity measures and complement indicators on capital and labour productivity. They can further be associated to indicators reflecting technological developments, innovation and economic competitiveness. This enhances their policy relevance as it sheds further light on concepts such as resource productivity and sustainable resource management.

Unfolding the indicators' constituents

The availability of detailed data on the composition and constituents of the indicators is an advantage for all indicators that focus on aggregate materials or material groups.

- The composition of the indicators provides information on the materials mix and on the major constituents, i.e. those material flows or industry sectors that contribute a relevant share to the aggregate results or even dominate them. This information is also a pre-requisite to address relevant sectors, which need to be involved in potentially effective intervention measures.

  Besides the aggregated information on MF and RP, it is essential that information on the main components of material use is made available to reflect the materials mix and shifts over time. As a general rule, this breakdown should at least cover the five major resource categories (energy carriers, construction minerals, metals, other minerals, biomass). An exception to this rule is when the indicators are to be used to monitor progress towards quantitative targets of a broad nature.

  The share of construction minerals, metals, industrial minerals, fossil fuels, and biomass (i.e. the major material resource categories) indicates which type of resource use and economic activity significantly contributes to the overall performance of the economy in physical terms. Like with the energy mix, countries have similarities but also differences with regard to the material resource mix. A closer look often reveals that some material categories, and within each material category certain materials, play a dominant or major role. This represents an important finding, and helps build a bridge towards those economic activities that are

especially challenged when resource productivity is to be enhanced and when material and natural resource use is to be further decoupled from the generation of value added.

- Some of the indicators may also be further disaggregated with regard to national or sub-national aspects. For instance, the domestic and foreign share of TMR provides important information on the degree to which countries develop by means of own or foreign resources. Monitoring these shares over time also allows to indicate the possible shift of environmental burden associated with resource use between countries and world regions.

Documenting the indicators – Interpretation in context

Interpretation in context requires a minimum of supplementary country-specific or issue-specific information. Such information should point at particular characteristics or features that help interpret the indicators in a broader national and international context. It should cover the main country-specific factors that have a bearing on the interpretation of the indicators (section 6.2).

Furthermore, the metadata should exist besides the data itself, providing the explanation of the meaning of the given indicator, giving the information on data sources used for indicator compilation, methodology and classifications used, uncertainties associated with the data, etc., so that the user can fully understand, use and analyse the data.

6.4. Communicating indicator results to a non-expert audience

A major objective of MF analysis is the provision of coherent and relevant information not only to researchers and analysts, but also to decision makers and the public. This is generally done via indicators. Most of these indicators need qualifications and careful interpretation due to methodological and empirical shortcomings, and due to differences in economies, often related to resource deposits, geography, demography and technology.

One should therefore not forget the efforts that need to be made to inform the users, the interested public and the press about the value, objectives and limits of the indicators derived from MFA. This actually turns out to be a key element to ensure proper use and interpretation of MFA results.

It is also important that indicator names are themselves self-explanatory and easily understandable by a broad audience, and that the use of the MFA jargon is avoided when disseminating and publishing the indicators. To ensure a maximum of coherence in terminology, the following examples are suggested:

- domestic processed output → waste and pollution from materials use.
- total domestic output → environmental burden of materials use
- direct material input → material supply

When communicating MF indicators to a non-expert audience, it is advisable to present them together with other indicators and/or associated with a reference value as described above. National MF indicators can also be presented together with international indicators harmonised at international level. This helps the users to better understand the meaning of the indicator and to minimise the risk of over-interpretation that is often associated with stand-alone indicators.

7. PRACTICAL MATERIAL FLOW INDICATORS FOR NATIONAL AND INTERNATIONAL USE

When developing MF indicators for national and international use, it is recommended to identify a set of indicators that collectively give the insights needed. To ensure that the indicators can be used as operational tools in the practical setting of governments' policies, the development of a national set of MF indicators should consider the desirable properties and the selection criteria described earlier in this guide, and include a balanced combination of various types of indicators. It should include:

- First, a few simple EW-MF indicators that characterise the materials basis of the economy and that capture developments in overall resource productivity.
- Second, selected issue-specific indicators that capture flows of materials of particular concern.
- Third, selected sectoral indicators that capture developments in resource productivity in major economic activity sectors and that can be used to reflect structural changes.

It should include both indicators that are adapted to the country's specific circumstances and policy needs, and indicators that can be used in international work and that are coherent with similar indicators used in other countries.

The number of indicators included in the set should not be too large so as to maintain the key function of indicators, i.e. simplifying the communication process and reducing the number of parameters that normally would be required to give an exact presentation of a situation. What is needed is a Core Set of indicators, including a few key indicators that can be used to attract public attention.

Simple EW-MF indicators

The aim of simple EW-MF indicators is to characterise the materials basis of the economy and to capture developments in overall resource productivity. These indicators should reflect major MF within the national economy, as well as between the national economy and different parts of the world, at aggregate level and broken down by major material groups to enhance interpretability.

The indicators selected should concentrate on the national and macro-economic level with emphasis on indicators that can also be used in international work, that are coherent with those used in other countries, and that enable the calculation of related regional aggregates (OECD totals, EU total, G8 total, etc.). Such indicators are also good candidates for inclusion in national sets of environmental or sustainable development indicators. Priority should be given to those indicators that benefit from an international consensus about their validity.

The aspects to be considered include:

- Which aggregate EW-MF indicators reflect best (i) overall resource productivity and (ii) economy-wide MF in the national context, in an international context.
- What major material groups should be covered in a systematic way to balance the message conveyed by the aggregate EW-MF indicators? At what level of detail? (e.g. "metals, other industrial minerals, construction minerals, fossil fuels, biomass"; "materials from renewable and non-renewable resources" or "biotic and abiotic materials", "primary raw materials and secondary raw materials").
- When a national set of environmental or sustainable development indicators already exists: which MF indicators complement best other core environmental and natural resource

indicators already in use? (water, forest, fish, energy resources, pollution issues, waste management issues).

They can be selected from the list of generic MF indicators described in section 3 that can be derived from simple economy-wide MF accounts and from international trade statistics. In the short term, priority can be given to indicators that capture direct flows with a systematic coverage of transboundary and trade related flows. In the medium and longer term, it is recommended that the indicators also cover hidden flows, i.e. unused domestic extraction and indirect flows associated with imports, to better reflect the entire material requirements of the economy and their potential environmental burden.

Issue-specific indicators

The aim of issue-specific indicators is to monitor individual MF of particular concern to the country and, if possible, to OECD countries as group or to any other relevant country grouping.

The aspects to be considered include:

- Which are the grouped or individual material flows whose monitoring appears to be most relevant in the national and international context? what level of detail should be considered? Examples include material groups such as: ferrous metals, non-ferrous metals, construction minerals, woody biomass, fish biomass, biofuels, recyclable materials; particular materials or substances such as: iron and steel, copper, mercury, lead, plastics.
- The materials to be covered should be identified according to commonly agreed upon criteria taking into account environmental and economic aspects. These criteria should take into account (i) the environmental significance of the various types of materials, i.e. their significance with respect to pollution issues and their significance with respect to resource management and waste management issues; and (ii) the economic significance of the various types of materials, i.e. their relative importance in flows within and among OECD countries, and between OECD countries as a group and the rest of the world (aspects related to trade, to supply security), their relative importance in flows within OECD countries. They should further bear in mind the links and complementarities with other environmental indicators already in use.

Issue specific indicators can be selected from the indicators described in the sections 5.4 and 5.5. They can be derived from physical input-output tables, individual MFAcc, substance flow analysis, as well as from economy-wide MF accounts, waste statistics and from international trade statistics.

Sectoral indicators

The aim of sectoral indicators is to monitor developments in resource productivity in major economic activity sectors. These indicators concentrate on the national meso-economic level.

Sectoral indicators can be selected from the list of MF indicators described in section 5.2. They can be derived from physical input output tables and decomposition analysis or from expanded economy-wide MF accounts, accounting for internal flows. Since the development and measurement of such indicators can easily get very resource intensive, it requires a careful consideration of the level of detail needed in line with available resources, and may need to be supported with a pilot study.

Aspects to be considered include:

- On what sectors should emphasis be placed when assessing resource productivity in the national context? In an international context?
- Which material flow and economic variables appear to be most appropriate to calculate productivity ratios at the meso-level (nominator, denominator, units)?

Chapter 5.
ESTABLISHING THE INFORMATION BASE

The analysis of material flows

usually builds on methodically organised accounts in physical units

- **Characteristics and functions of material flow accounts**
- **Recommendations for a first implementation**
- **Implementation modules**

ESTABLISHING THE INFORMATION BASE

1. MATERIAL FLOW ACCOUNTS

MF analysis and related indicators need to be based on a solid and reliable information base. This information base is usually provided by MF accounts, but can also build on other statistical tools and databases. Like other environmental accounts, MF accounts have the advantage of methodological robustness and coherence that is important in the context of international work and that helps among others portray countries with varying domestic resource endowments on a somehow equal footing.

1.1. Main characteristics

Material flow accounts (MFAcc) are methodically organised accounts in physical units (usually in tonnes) that quantify the flows of different types of materials into, out of and possibly within a given system at different levels of detail and completeness.

A main feature of MFAcc is the use of the materials balance principle (Chapter 3.1.2). By making reference to the material balance principle, MFAcc capture the inputs to the system (e.g. resources extracted or harvested from the surrounding natural environment or imported from other systems), flows through the system (from raw material production to final consumption) and outputs from the system (e.g. in the form of pollution or waste, or in the form of exports to other systems).

Another important feature of MFAcc is that, unlike other physical flow accounts, they track both direct flows (i.e. flows of materials physically entering the economic process) and indirect and unused flows (i.e. flows of materials not entering the economic process, but associated to resource exploitation and to the up-stream production process of a product and of relevance from an environmental point of view).

The accounting concepts involved are founded on the first law of thermodynamics, which leads to the following accounting identity:

natural resource extraction + imports = residual output + exports + net addition to man-made stocks

i.e. the sum of material inputs into a system equals the sum of its material outputs, thereby comprising the materials accumulated as changes in stocks.

INPUTS (origin)		**OUTPUTS (destination)**
Domestic extraction used (DEU)		**Emissions and waste**
Minerals (metals, other industrial minerals, construction minerals)		Waste landfilled Emissions to air, water, land
Biomass		**+ Dissipative use of products and losses**
Fossil fuel carriers (oil, coal, gas)		**= Domestic processed output to nature (DPO)**
+ Imports (IMP)		
= Direct material input (DMI)	**Net additions to stock (NAS)**	**+ Disposal of unused domestic extraction (UDE)**
+ Unused domestic extraction (UDE)	Infrastructure and buildings	
from mining/quarrying	Other (machinery, durable goods, etc.)	from mining/quarrying
from biomass harvest		from biomass harvest
from soil excavation		from soil excavation
= Total material input (TMI)		**= Total domestic output to nature (TDO)**
+ Indirect flows associated with imports (IFimp)		**+ Exports (EXP)**
		= Total material output (TMO)
= Total material requirements (TMR)		

The system to which the accounts apply is usually a socio-economic system with its production and consumption activities, and its interactions with the surrounding environment and with other socio-economic systems and their environment. It is these interactions that are of interest to MFAcc. They track the flows of materials from extraction and harvesting through product manufacture, use, reuse, and recycling to final disposal, including discharges to the environment that are associated with each stage of these flows.

The accounts can record internal flows of the system by referring to internal partitions that are relevant for the specific purpose of the study (e.g. flows of materials between economic activity sectors or industries) or deal with the system as a black box, recording only the flows that cross the system's boundary with the surrounding natural environment and with other similar systems.

MFAcc can be established at various levels of scale (world regions, whole national economy, branches of production, firms, municipalities, etc.) and can be applied to materials at various levels of detail (all materials, groups of materials, individual materials or substances). A theoretical framework for a system of national MFAcc[47] that can support MFA in line with the SEEA is described in Volume II. Data availability permitting MFAcc can be disaggregated in several ways, such as by industry sectors, geographic areas, particular materials, products and time periods. The accounting concepts used can also be applied to non-economic natural systems such as ecosystems, habitats or river basins. This can be represented schematically in various ways (Figure 3, p.46).

MFAcc are descriptive, not normative

MFAcc organise data on material flows in a way that enables analysis, modelling and insights not apparent from the scattered information from which they are assembled. Compared to other measurement tools, complete national MFAcc for example have the potential to provide a holistic and integrated view of resource flows through the economy and to also capture flows that, though not entering the economy as objects of transactions, are relevant from an environmental point of view. (Figure 1, p.42, Figure 2, p.42).

EW-MFAcc are value neutral in that they include all materials regardless of their economic importance or their environmental impacts. Such accounts can form an "objective" information basis for various types of analyses and assessments:

- They can be used as a basis for assessing the environmental impacts associated with natural resource and materials use when combined with environmental impact assessment (eIA) tools or with information from life cycle assessment (LCA).
- They can be used as a basis for assessing the economic costs and benefits associated with natural resource and materials use when combined with environment-economy models or with value chain analysis.

MFAcc are expressed in physical units

The use of physical units reflects the nature of the interactions between the economy and the environment that manifest themselves in physical terms: materials and energy extracted from the environment and moved or transported from one place to another are physical entities, and the changes induced in the environment as a result of economic activity (depletion, degradation) are physical by definition. The use of physical units also partly reflects the historical concern with physical scarcities, which was an important driver for the establishment of natural resource accounts in the 1970s and 1980s.

An accurate physical description of production and consumption processes is a prerequisite for the management of their environmental implications. It also helps avoid complicated indexing that is usually required when economic values are used. Physical measures of material flows expressed in

47 Based on the accounting principles of the SEEA.

mass units are of interest to economists and environmentalists in a number of areas. These include areas related to waste and materials management, to the transport of materials and goods, to distributional issues, to international trade,(e.g. to satisfy demands for raw materials), to future markets and to technology developments.

Physical units can be weight units, energy content units or volume units. MFAcc being based on the law of conservation of matter, weight units (i.e. tonnes) are used as the best proxy for the mass of the materials monitored, which is invariant to their chemical and physical transformation.

Expressed in physical terms, data from MFAcc enable and benefit from linkages with environmental statistics and analysis. They can easily be connected to and/or derived from environmental information on pollution or waste generation, and can be related to environmental risks (e.g. from transport of materials) and to information on available stocks or reservoirs of natural resources.

By using common units, aggregation and the presentation of results in the form of simple indicators is facilitated. Aggregation has however its limits and may entail a risk of misinterpretation if these limits are ignored and when aggregate measures are inappropriately used for purposes for which they were not designed for (Chapter 4.3.5).

National MFAcc are structured like national economic accounts

National MFAcc are structured as a satellite system to the National Accounts, and make wide use of SNA's definitions and classifications. (see Volume II for further details). This facilitates the joint analysis of environmental and economic policy issues.

Data from national MFAcc can easily be connected to economic information, trade statistics, industry statistics, price information, etc. Used in combination with these other types of information, they enable a comparison of environmental benefits and economic costs, and of environmental burden and economic benefits[48] of natural resource and materials use. They can also be used to measure resource productivity and various types of environmental and sustainable development indicators, and form a basis for modelling and forecasting to support longer term decision making.

National MFAcc are an integral part of environmental accounting

National MFAcc are part of the physical flow accounts family as described in the System of integrated Environmental and Economic Accounting (SEEA). They relate closely to other types of natural resource and environmental accounts, including hybrid flow accounts comparing physical quantities to matching economic flows, such as NAMEAs (National Accounts Matrix including Environmental Accounts).

When applying the accounting principles of the SEEA to the compilation of economy-wide and of other comprehensive MFAcc, there are a few methodological aspects that need to be considered:

> The SEEA distinguishes four major types of flows for which accounts in the form of supply and use tables can be developed:
>
> - natural resources,
> - ecosystem inputs,
> - products, and
> - residuals.
>
> Accounting tables for these four flows can be assembled into a single table showing the balance of material accumulation in the economy.

- Most physical flow accounts in the SEEA are restricted to direct physical flows, i.e. flows that are observable at the boundary of or within the economy and for which statistical observation is feasible. Economy-wide and other comprehensive MFAcc cover also indirect and unused physical flows that do not enter the economy and remain in the environment after having been moved or displaced by human activities. Recording these "hidden" flows helps reflecting the scale of the potential environmental burden of natural resource and materials use. Constructing MFAcc in line with

[48] See also Gravgard Pedersen, de Haan, *The SEEA 2003 and Physical Flow Accounting*, Journal of Industrial Ecology, vol. 10, number 1-2, 2006.

the SEEA therefore requires extending the SEEA accounting principles to the full materials balance and to the so-called hidden flows.

- Economy-wide MFAcc have been constructed according to the territory principle, as are environment and energy statistics (i.e. they account for activities on the national territory), whereas national accounts and the SEEA recommend the use of the residence principle (i.e. they account for activities of resident economic units). The difference between the two principles relates mainly to international transport of goods and persons, and to the associated environmental and energy implications. This should not be seen as a major obstacle, but may raise interpretation issues when the results are communicated in the form of indicators. It is therefore recommended to carefully define the system boundaries used for the construction of the accounts and, when necessary, to accompany economy-wide MFAcc with bridge tables to reconcile the two approaches.

These questions are being debated as part of the finalisation of the SEEA as an international statistical standard.

1.2. Main functions and analytical applications

A main function of MF accounts is to provide a coherent, multi-purpose database, at the bottom of the information pyramid, for carrying out in-depth studies and policy analysis, and for answering policy questions about natural resource and materials management and use. Like other physical flow accounts[49], MFAcc can be used to help understand the interrelationships between the natural environment and the economic system. The aim is to see the extent to which the economy is dependent on particular environmental inputs, including via trade, and the extent to which the environment is sensitive to particular economic activities, and to identify which environmental pressures exist and where. The information developed from undertaking such an analysis may be used to construct any relevant indicators that report on aspects of natural resource and materials management.

Some MFAcc allow the identification of "hot spots" in the use cycles of the materials they analyse, such as e.g. their main points of entry in the system and of release into the environment. This is the case with MFAcc focusing on individual industrial materials or on substances. Relevant tools include individual material flow accounts (for resources such as timber, selected energy carriers or mineral resources, water), at various levels of detail and application, and substance flow accounts.

The use of MFAcc in policy analysis is often less information-intensive than its use in materials management or productivity analysis, but may remain labour intensive depending on the scale of application and the type of analysis to be performed. Where the accounts trace the flow of natural resources from the environment to the economy and within the economy, they provide information about the impacts of sectoral economic activities on the resource flows and stock and vice versa. Where the accounts trace the flows of natural resources and materials among countries or among world regions, they provide information about the impacts of trade and globalisation on resource flows and stocks and about induced structural changes.

Relevant tools include physical input-output analyses and decomposition analyses based on PIOTs and on NAMEA-type approaches, broken down by economic sectors or industrial branches and by materials or groups of materials, as well as complete economy-wide MFAcc.

MFacc complement other types of natural resource accounts that do not make reference to the material balance principle. They can be combined with asset accounts that deliver information on natural resource stocks. They can be combined with monetary accounts to construct hybrid tables and support integrated analyses.

49 Natural resource accounts (e.g. forest resource accounts or water resource accounts), energy accounts and balances, etc.

2. RECOMMENDATIONS FOR A FIRST IMPLEMENTATION

When undertaking a national effort to develop and implement material flow accounting, it is essential to carefully consider the purposes and uses for which the accounts are to be established, the institutional arrangements and partnerships that are required to ensure continuity in the effort, the costs/benefits of creating and maintaining the accounts, and the statistical basis available for populating the accounts. Often a combination of tools proves more useful to inform policy. The robustness and applicability of MFAcc can be enhanced by integrating different MFA tools and by using hybrid approaches.

In theory, MFAcc can be constructed like other physical flow accounts described in the SEEA in the form of supply-use tables, by extending them to the full materials balance and to the so-called hidden flows. This has the advantage of ensuring a maximum of coherence with national accounting principles and enables the construction of MF accounts that are as good as economic accounts.

In practice, most MFAcc in use have been constructed on the basis of economy-wide accounting principles having a different purpose in mind, and experience shows that some flexibility is needed for the practical implementation of MF accounts.

2.1. Defining the purpose and the level of ambition of the effort

The issues to be considered and the questions to be answered are as follows:

- What is expected to be achieved with the accounts? Are there any particular problems that are to be addressed? What is the audience, who are the main users?
- How much will the establishment and maintenance of the accounts cost? How many people are needed and with which expertise? How can continuity in expertise and funding be best secured?
- What are the pros and cons and the costs and benefits of different alternatives? Could similar results be obtained at lower costs, e.g. by better using existing statistics without compiling full accounts? Or by combining data from MF accounts with other statistics and information tools?

MFA has many potential uses and users and can support a variety of public and private policies and actions. To identify which type of MFAcc is most suitable and relevant, the particular purposes for which their results are to be used need to articulated and prioritised and discussed with all relevant partners, including potential users and policy makers who should be involved as early and as closely as possible in the development of the accounts. Involvement of these partners can be lengthy but has significant pay-offs in terms of acceptance of results.

It is recognised that a complete implementation of MF accounts can be very ambitious and is not necessary for particular studies or purposes. It is therefore essential that the scope of the effort takes into account not only the purposes for which the accounts are to be used, but also the expertise and the resources (budget, staff) that are or can be made available. This is to avoid overly ambitious theoretical system-building and to resist the temptation to engage in a large, indiscriminate data compilation that could emerge as an end in itself, and that could hinder the establishment of a regular, continued process.

It is further recognised that, in many areas, MFAcc are generally not the only tools available to support decisions. Other tools exists and are used. To identify which tool or which combination of tools is the most relevant for a given purpose, it is important to understand well the merits and drawbacks of the

various tools and how they relate to each other, and to review the value added and the costs of creating accounts.

In short, work on MFAcc needs to be concrete, user-oriented and pragmatic in its ambitions. This can be done by concentrating first on a few simple accounts where it is possible to achieve results in the relatively near future, and where potential users are most willing and able to use the results, for example to solve or inform about particular problems.

Such simple accounts can focus on particular materials[50] (e.g. metals such as copper or aluminium, energy carriers such as oil; or hazardous substances such as arsenic, lead, mercury, cadmium) or on particular stages in the materials production and consumption cycle and for which basic data are readily available (e.g. material inputs).

These simple accounts can subsequently be expanded in a step-wise manner.

2.2. Institutional arrangements and partnerships

The issues to be considered and the questions to be answered are as follows:

- Which government and non-government bodies need to be involved? How should they best work together? How can continuity in the effort be best secured?
- Which partnerships could be established with other countries? How to benefit from international work in the field?

The way responsibilities for carrying out MF and other environmental accounting are shared and arranged at national level vary among countries. It largely depends on a country's administrative culture, on its overall institutional set up and arrangements, and on how different policies developed over time.

Arrangements include work led by statistical agencies, environment ministries, environment agencies, and private institutions. Originally, much research and analysis, as well as pilot projects have been done by non-government groups that have accumulated a lot of the expertise needed (academics such as universities and research institutes, consultant firms, etc.) sometimes with government funding and/or in co-operation with government agencies. Government agencies usually play a lead role when the work is becoming a regular activity and when the results are being used in policy making. The production of MF accounts and data is generally in the hands of national statistical offices (NSOs) as part of their environmental accounting activities or as part of their country's official statistics. The development and publication of material flow indicators, and their use in environmental reporting is often shared among NSOs and environment agencies and ministries, and sometimes research institutes.

The construction of national MFAcc, at whatever level of completeness and detail as for the materials covered, requires the implementation of National Accounting expertise. In this context, co-operation between national and environmental accountants is highly rewarding and a low-cost business.

In countries where MF work is well advanced, partnerships are commonly established among various partners within the country as well as with international networks and with partners in other countries.

There is therefore no unique scheme nor optimal arrangement that could be applied or recommended. It is rather up to each country to identify the most appropriate and cost-effective way of sharing

50 Among the challenges are how to choose what materials to track and at what level of detail. This is of importance when indicators are to be developed, and when accounts are to be used to address particular problems. In those cases the material flows to be monitored should be those that are most closely interlinked with the issues or question to be addressed. When the purpose is to support decisions aiming at mitigating the negative environmental impacts of the production and consumption of materials, it is important to address both the quantity and the "hazardous" character of the materials. This can be done by using hybrid approaches combining for example material system analysis and life cycle cycle analysis.

responsibilities and of ensuring coordination within the country and with relevant international organisations. There are however several institutional factors that are important to foster acceptance and credibility of the accounts, among which the following:

- Securing continuity of work in one institution (and a stable budget);
- Consultation and consensus-building with domestic stakeholders and co-operation with sectoral ministries and decision-making bodies (energy, economics, transport, agriculture, water boards, etc.) and when appropriate with sub-national authorities;
- Presence and recognition of a country's environmental accounts at the international level.
- Institution of partnerships with non-governmental groups.
- Involvement in international work and institution of partnerships with other countries.

2.3. Identifying available statistical sources

The issues to be considered and the questions to be answered are as follows:

- What is the statistical basis that is available or can readily be made available to populate the accounts? Who are the providers of these statistics?
- How much additional data work (collection, estimation, new surveys) will be required?

MFAcc aim at providing a well structured framework that can integrate existing and future data flows. When setting up a system of MFAcc, one should therefore exploit to the utmost possible existing data bases and data collection processes and minimize additional efforts. When the focus is on selected individual materials or substances and on industry branches (e.g. in input-output tables), one also needs to consider data confidentiality and security issues that might be of concern to industry.

Data on "material" resources needed to populate national material flows accounts are generally easy to collect, in particular for simple EW-MFAcc. In most countries, much data is already available in official statistics and can also be derived from international sources, and MFAcc generally do not require a lot of new data collection. Main data sources for compiling direct flow accounts are resource extraction statistics, foreign trade statistics, production statistics, agricultural statistics, national accounts, waste statistics, emission inventories and other environment statistics.

Since most of these data are spread across different publications and databases and handled by different institutions, the first task is to identify the original sources and collate the data. A second task is then to check, revise and supplement these data and combine them in a coherent framework so as to make them fit for the purpose of MFacc.

Their integration into a coherent set of data may be complicated by the fact that many of the data available are structured and compiled in different ways. Conventional environmental statistics for example must be adjusted to national accounts definitions and classifications before they can be used to populate material flow accounts. Environment statistics are often collected with particular policy, regulatory or administrative purpose in mind and the way they are structured is specific to this purpose and is often not compatible with economic accounts.

Comparability between physical and monetary data is ensured by the use not only of the same definitions and classifications, but also of practical implementation steps. To the extent that data on physical quantities and values are collected together, it is in principle possible to perform the same elaborations in order to arrive at aggregates that fully correspond to each other.

When setting up material flow accounts at the sub-national (territorial) level, data availability is generally much lower than at the national level, and their compilation may be more time consuming. The two main differences between the national and the territorial level concern data on import (and

export) flows and the confidentiality of data. On a territorial level trade flows have to be separated into physical flows between the territory and the rest of the country, and physical flows between the region and the rest of the world. Confidentiality of data on a territorial level could be a problem if the production structure in a certain branch within the region is dominated by a small number of firms.

2.4. Interpretation and dissemination of results

A major objective of MFAcc is the provision of coherent and relevant information not only to researchers and analysts, but also to decision makers and the public. This generally done via indicators. Most of these indicators as well as other results of MFacc need qualifications and careful interpretation due to methodological and empirical shortcomings, and due to differences in economies, often related to resource deposits, geography, demography and technology.

One should therefore not forget the efforts that need to be made to inform the users, the interested public and the press about the value, objectives and limits of the information and various indicators derived from MFAcc so as to ensure proper use and interpretation of results. These limits and other factors having a bearing on the interpretability of MF results are discussed in Chapter 4.6.

3. IMPLEMENTATION MODULES[51]

When macro-level accounts are set up mainly for the purpose of indicator development, the level of detail and the compilation effort can be kept to a minimum. Experience however shows that when indicators derived from these accounts start to be used, this often creates a demand for additional data and analysis, which may lead to a subsequent expansion of the accounts in a multi-level and multi-dimensional way. The highest level of detail, feasible with available resources, should therefore be considered when establishing the databases and accounts underlying the indicators. This facilitates their stepwise expansion to include for example a breakdown by industry sector, or a better coverage of trade flows by country or region of origin or destination.

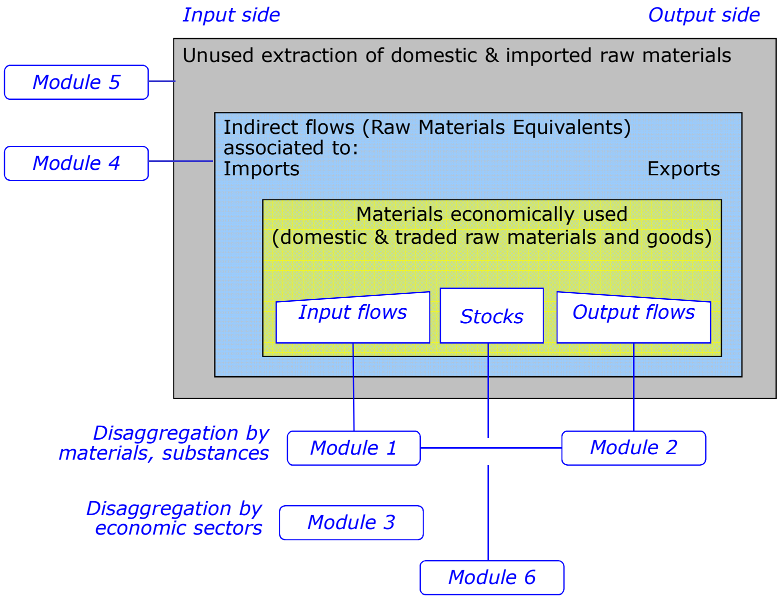
This sequence of steps is explained in detail in an implementation guide that will be prepared. The implementation guide explains how to compile national MFAcc covering the full material basis of the economy at the highest possible level of detail and using tonnes as the common physical unit. It can be used to produce both so-called economy-wide accounts in which the different materials can subsequently be aggregated by major material groups or to an overall total, and national accounts for selected individual resources and materials.

Developed jointly with Eurostat, it is based on a menu of options that helps establish national MFAcc in practice and identify the most appropriate data sources and methods considering available resources and data shortcomings.

It is constructed in a modular way to reflect several levels of ambition and completeness of accounts, and is designed so that it can be implemented equally well in part or in whole. It includes a didactic part with a set of simple MF accounts to allow newcomers to join in and demonstrating what can be achieved with modest resources. These simple accounts strive to increase homogeneity through establishing base tables by group of material at national level. At the same time, these tables are only core tables of a broader set. When countries are starting with the development of MF accounts and have a choice in constructing MF measures, these base tables may provide a guide.

51 Based on original proposals by Heinz Schandl.

Figure 8. Hierarchy and sequence of steps for a system of national MFAcc



Taking into account the average availability and quality of underlying data series, base tables can be compiled in a sequence of steps starting with the input side of the flow accounts and be progressively expanded to cover other flow aspects up to a full materials balance. Progressing through the sequence of accounts and tables, more primary data and compilation work is required. Disaggregation by materials or material categories that is relatively easy to implement is part of the first steps; disaggregration by economic activities that is less easy to implement is part of subsequent steps.

Module 1 focuses on the compilation of simple MF accounts at national level that trace input flows into the economic system, disaggregated by materials and material categories. The economic system itself is treated as a black box in this module. Module 1 can be used to establish accounts that measure the flows of particular resources or materials into the economy and emissions from it.

Module 2 expands Module 1 by adding base tables and core variables on output flows to establish simple material flow balances. The economic system itself is treated as a black box in this module. Module 2 can be used to establish accounts that measure the flows of particular materials or residuals from the economy (exports, pollutants, waste).

Module 3 will disaggregate MF data by economic activities, thereby opening up the black box. It benefits from IO work and the existence of MIOTs and PIOTs. Module 3 can be used to measure the contribution of economic activity sectors to the flows of materials in the economy and to monitor structural changes.

Module 4 will address up-stream flows related to imports (as well as to exports) according to the concept of raw-material equivalents for assessing the material advances for imports (exports).

Module 5 will address the side effects of the extraction of materials in a national economy, i.e. unused extraction not entering the economic process but having an environmental significance.

Module 6 will suggest an approach for directly assessing the changes in material stocks in a national economy.

Each of these modules provides a basis for deriving material flow indicators (Table 12).

Table 12. Attribution of MF indicators to accounting modules

No. of the module	Basic MF indicators and related accounting variables	Efficiency indicators*	Other MF indicators and indicators for particular material flows
Module 1	Domestic extraction (DE) Imports (IM) Direct material input (DMI)	GDP* per DMI	DMI per capita DEU per area IMP per DMI DEU per DMI IMP per price of imports Share of renewables in DEU Share of renewables in DMI DMI_{REC} Flows of particular interest
Module 2	Exports (EXP) Emissions and wastes (EW) Dissipative use of products (DUP) Domestic material consumption (DMC) Domestic processed output (DPO) Net additions to stock (NAS) Physical trade balance (PTB)	GDP* per DMC GDP* per DPO	DMC per capita DPO per capita DMC per area DPO per area NAS per area IMP per DMC DEU per DMC EW per DPO DUP per DPO EXP per price of exports Flows of particular interest
Module 3	DMI by economic sectors DMC by economic sectors DPO by economic sectors	Gross value added* of particular sector per sectoral DMI Gross value added* of particular sector per sectoral DMC Gross value added* of particular sector per sectoral DPO	Flows of particular interest
Module 4	Raw material equivalents of imports (RME_{IMP}) Raw material equivalents of exports (RME_{EXP}) Raw material input (RMI) Raw material consumption (RMC) PTB based on RME_{IMP} and RME_{EXP}	GDP* per RMI GDP* per RMC	RMI per capita RMC per capita IMP per RME_{IMP} EXP per RME_{EXP} Share of renewables in RMI Flows of particular interest
Module 5	Unused domestic extraction (UDE) Domestic total material requirement (domestic TMR) Total unused extraction (TUE) Indirect flows of imports (IF_{IMP}) Indirect flows of exports (IF_{EXP}) Total material requirement (TMR) Total material consumption (TMC) PTB based on IF_{IMP} and IF_{EXP}	GDP per TMR GDP per TMC	TMR per capita TMC per capita UDE per domestic TMR TUE per TMR Sum of IMP and IF_{IMP} per TMR Sum of IMP and IF_{IMP} per TMC Sum of DEU and UDE per TMR Sum of DEU and UDE per TMC Share of renewables in TMR TMR_{REC} Flows of particular interest
Module 6	Gross additions to stock (GAS) Net additions to stock (NAS)	n.a.	GAS per DMC incl. input balancing items NAS per area Flows of particular interest

* Depending on the MF variable used, adjustments to the economic variable may be needed to ensure the statistical coherence between the two parts of the ratio.

Source: OECD.

ANNEX. GLOSSARY OF TERMS RELATED TO MATERIAL FLOW ANALYSIS AND RESOURCE PRODUCTIVITY

This glossary includes a list of terms and definitions related to material flow analysis (MFA) and resource productivity (RP) compiled from OECD and other international sources (glossaries, manuals, reference documents). It provides a basis for a common language on MFA and RP at international level.

Please note that:

- The glossary makes no claim for completeness.
- In some cases, it is appropriate to refer to several definitions depending on the context in which the term is used. Some terms have for example a general (user-friendly) definition, as well as a more specific, technical definition when used in the context of environmental-economic accounting. In this case, keeping the two kinds of definitions is essential to make the underlying concepts understandable to a broader audience.
- Terms and definitions already agreed upon elsewhere and compiled from existing and glossaries and publications have been kept as they are, but are accompanied with further specifications when appropriate.

Glossary of terms related to material flow analysis and resource productivity

Glossary of terms related to material flow analysis and resource productivity

Accounts

An account is a tool which records, for a given aspect of economic life, (a) the uses and resources or (b) the changes in assets and the changes in liabilities and/or (c) the stock of assets and liabilities existing at a certain time; the transactions accounts include a balancing item which is used to equate the two sides of the accounts (e.g. resources and uses) and which is a meaningful measure of economic performance in itself.
Source: SNA 2.85 & 2.87

Aggregation

Aggregation is the process of adding variables or units with similar properties to come up with a single number that represents the approximate overall value of its individual components.
Source: UNDESA, 2000

Aggregation is the combination of related categories, usually within a common branch of a hierarchy, to provide information at a broader level to that at which detailed observations are taken.
With standard hierarchical classifications, statistics for related categories can be grouped or collated (aggregated) to provide a broader picture, or categories can be split (disaggregated) when finer details are required and made possible by the codes given to primary observations.
Source: "United Nations Glossary of Classification Terms".

Aggregation in physical accounts

In environmental accounting, aggregation is often used as a mean to improve the interpretability of physical flows accounts grouping materials with a common characteristic, or contributing to a specific environmental issue through a weighting system, e.g. the carbon dioxide equivalent, the ozone depleting potential, acidifying potential, etc.
Source: SEEA 3.26

Assets

Assets are entities functioning as stores of value and over which ownership rights are enforced by institutional units, individually or collectively, and from which economic benefits may be derived by their owners by holding them, or using them, over a period of time (the economic benefits consist of primary incomes derived from the use of the asset and the value, including possible holding gains/losses, that could be realised by disposing of the asset or terminating it). See also Natural assets
Source: SNA 10.2 &13.12

Biological (or biotic) resources

Timber resources, crop and plant resources, aquatic resources, and animal resources other than aquatic that bring use benefits today or that may do so in the future. Each category of biological resource in the SEEA asset classification is subdivided into cultivated and non cultivated sub-categories.
Source: SEEA 7.53

Non-cultivated biological resources

Non-cultivated biological resources consist of animals and plants that yield both once-only and repeat products over which ownership rights are enforced but for which natural growth and/or regeneration is not under the direct control, responsibility and management of institutional units. For biological resources "non-cultivated" is synonym of "non-produced". The SEEA adds non-cultivated resources that provide no current use benefit but that may one day do so (that is those with current option and bequest benefits).
Source: SNA (AN.213) / SEEA 7.54

Cultivated biological resources

Cultivated biological resources correspond to cultivated fixed assets and work in progress on cultivated assets in the SNA. The SEEA clarifies the SNA definition: cultivated fixed assets are "livestock for breeding, dairy, draught, etc. and vineyards, orchards and other trees yielding repeat products whose natural growth and/or regeneration is under the direct control, responsibility and management of institutional units". Work in progress on cultivated assets "livestock raised for products yielded only on slaughter, such as fowl and fish raised commercially, trees and other vegetation yielding once -only products on destruction and immature cultivated assets yielding repeat products".
Source: SEEA 7.57

Black box

The term "black box" is used in material flow accounting to characterise the system under scrutiny when the purpose is to record flows that cross the system boundary and not flows that are internal to the system.

In national economy-wide material flow accounting the term "black box" is used to characterise the whole economic system, reflecting the fact that only flows crossing the system boundary between the national economy and the environment and between the national economy and the rest of the world are recorded.
Source: OECD.

Clean production

Manufacturing processes that minimise environmental impacts (e.g. low use of energy and raw materials, low emissions and waste) through changes in production processes.
Source: OECD.

Commodities, see Products

Composite (or compound) material, see Materials

Cross border residual flows

Flows of residual that cross the national border; they consist in discharge from production into a different environment and the transmission of residuals from one environmental sphere to another by natural mechanisms.
Source: SEEA 3.92 & 3.93

Decoupling

Decoupling refers to breaking the link between "environmental bads" and "economic goods." Decoupling occurs when the growth rate of an environmental pressure is less than that of its economic driving force over a given period. Decoupling can be either absolute or relative. Absolute decoupling is said to occur when the environmentally relevant variable is stable or decreasing while the variable reflecting the economic driving force is growing. Decoupling is said to be relative when the growth rate of the environmentally relevant variable is positive, but less than the growth rate of the variable reflecting the economic driving force.
Source: Indicators to measure decoupling of environmental pressure from economic growth, OECD, 2002

Dematerialisation

The term "dematerialisation" has been used to reflect an absolute or relative reduction in the use of material and energy per unit of value added or output.
Source: Economy-wide material flow accounts and derived indicators – A methodological guide, Eurostat, 2001

Depletion

The depletion of renewable resources, refers to the part of the harvest, logging, catch and so forth above the sustainable level of the resource stock (i.e. faster than they can be renewed). The depletion of non-renewable resources, refers to the quantity of resources extracted.
Source: based on UNSD, Glossary of Environment Statistics, 1997

In environmental accounting, the depletion of natural economic assets is the reduction in the value of deposits of subsoil assets as a result of their physical removal, … of water resources, and … of natural forests, fish stocks in the open seas and other non-cultivated biological resources as a result of harvesting, forest clearance, or other use.
Source: SEEA 7.168, SNA 12.29, 12.30

Degradation (environmental)

Environmental degradation is the deterioration in environmental quality from ambient concentrations of pollutants and other activities and processes such as improper land use and natural disasters.
In environmental accounting, degradation refers to the decrease in environmental functions or services rendered by the environment.
Source: based on UNSD, Glossary of Environment Statistics, 1997, and SEEA 10.142

Direct (material) flows

In material flow accounting, direct materials flows refer to flows of materials that physically cross the boundary of the economic system (*at the level for which the accounts are made, i.e. the national economy in the case of national economy-wide material flow accounts)* either as an input or as an output. Direct flows refer to the actual mass (weight) of the material or product that enters or leaves the system and do not take into account the life-cycle dimension of the production chain.
Source: OECD. (based on Eurostat 2001)

Direct Material Input (DMI)

Direct Material Input (DMI) is a variable used in material flow accounting. DMI measures the direct flows of materials that physically enter the economic system as an input, i.e. materials that are of economic value and that are used in production and consumption activities. In economy–wide material flow accounting DMI equals domestic (used) extraction plus imports.
Source: OECD. (based on Eurostat 2001)

Direct Material Output (DMO)

Direct Material Output (DMO) is a variable used in material flow accounting. DMO measures the direct flows of materials that physically leave the economic system after use in production and consumption activities as an output either to the environment or to the rest of the world. In economy–wide material flow accounting, DMO equals Domestic Processed Output (DPO) plus exports.
Source: OECD. (based on Eurostat 2001)

Dissipative (material) flows

Dissipative (material) flows refer to materials dispersed into the environment as a result of product use.

In material flow accounting they are defined as the mass (weight) of materials, which are dispersed into the environment as a deliberate, or unavoidable (with current technology) consequence of product use. These flows comprise two components:

- Dissipative uses. i.e. dispersion of materials as a consequence of product use on agricultural land or roads (e.g. fertilisers and manure spread on fields, or salt, sand and other thawing materials spread on roads).
- Dissipative losses. i.e. dispersion of materials as a consequence of the corrosion and abrasion of products and infrastructures, leakages, etc. (e.g. rubber worn away from car tires, particles worn from friction products such as brakes, abrasion from roads, losses due to evaporation of e.g. water or other solvents used in paints or other coatings).

Source: OECD (based on Eurostat 2001 and WRI)

Domestic Material Consumption (DMC)

Domestic Material Consumption (DMC) is a variable used in material flow accounting. DMC measures the mass (weight) of the materials that are physically used in the consumption activities of the domestic economic system (i.e. the direct apparent consumption of materials, excluding indirect flows). In economy–wide material flow accounting DMC equals DMI minus exports, i.e. domestic extraction plus imports minus exports.
Source: OECD (based on Eurostat 2001)

Domestic Processed Output (DPO)

Domestic Processed Output (DPO) is a variable used in material flow accounting. DPO measures the mass (weight) of materials that physically leave the domestic economic system after use in production and consumption activities as an output to the domestic environment, i.e. as residuals. Included in DPO are emissions to air, industrial and household wastes deposited in landfills, material loads in wastewater and materials dispersed into the environment as a result of product use (dissipative flows). These flows occur at the processing, manufacturing, use, recovery and final disposal stages of the economic production-consumption chain.
Source: OECD (based on Eurostat 2001)

Domestic Total Material Requirement (domestic TMR)

Domestic Total Material Requirement (domestic TMR) is a variable used in material flow accounting. Domestic TMR measures the mass (weight) of material flows originating from the national territory, i.e. domestic used and unused extraction. In economy–wide material flow accounting, domestic TMR equals TMI minus imports.
Source: OECD (based on Eurostat 2001)

Eco-efficiency

Eco-efficiency is a generic term used to designate a management strategy based on quantitative input-output measures and which seeks to maximise the productivity of energy and material inputs in order to reduce resource consumption and pollution/waste per unit output and to generate cost savings and competitive advantage.
Source: OECD, based on Sustainable production and consumption – Clarifying the concepts, OECD, 1997

Eco-efficiency indicators

There is no commonly agreed upon definition for eco-efficiency indicators. The term usually designates indicators that represent the output or value added generated per unit of 'nature' (materials, energy, pollution) used. The inverse is eco-intensity indicators. When applied to natural resources or to materials, the terms resource or materials efficiency are often used as synonyms for resource or materials productivity. See "Productivity".
Source: based on Eurostat 2001

Eco-efficiency profiles

Eco-efficiency profiles (also called "environmental economic profiles") combine economic contribution and environmental burden by industry. The economic contribution is represented, for example, by the percent each industry contributes to GDP or employment. The environmental burden is represented by the percent each industry contributes to the emission of various residuals, or the use of materials and energy.
Source: SEEA 4.101

Eco-intensity indicators

There is no commonly agreed upon definition for eco-intensity indicators. The term usually designates indicators that represent the "use of nature" (materials/energy/pollution) per unit of value added or output. The inverse is eco-efficiency indicators.

Examples of eco-intensity indicators are: the Material Intensity Ratio (MIR), a ratio reflecting material resource use in tonnes per currency unit of output, and the Material Input Per Service (MIPS), a unit of measurement developed by the Wuppertal Institute, whereby the material intensiveness of various products and services is monitored in relation to a single commodity unit produced.

Source: based on Eurostat 2001

Ecological footprint

The Ecological Footprint measures how much productive land and water an individual, a city, a country, or humanity requires to produce all the resources it consumes and to absorb all the waste it generates, using prevailing technology. This land could be anywhere in the world. The Ecological Footprint is measured in global hectares.

Source: Global Footprint Network – Footprint Term Glossary [http://www.footprintnetwork.org/gfn_sub.php?content=glossary#gha].

Ecological rucksack

The term 'ecological rucksack' is used to designate the life-cycle-wide material requirements (i.e. the total input of primary materials and energy) associated with the production of a product. It measures the life-cycle-wide material input during all upstream production stages minus the mass of a product itself. The term is used as a synonym for indirect material flows or up-stream flows.

Source: based on Eurostat, 2001

Economy-wide

The term "economy-wide" is used in material flow analysis to designate MFA tools that cover the entire range of materials exchanged at the boundary of the national economy and whose results can be used to provide an aggregate overview of annual material inputs and outputs of an economy.

Economy-wide material flow accounts, see Material Flow Accounts

Ecosystem inputs

Ecosystem inputs cover the water and other natural inputs (e.g. nutrients, carbon dioxide) required by plants and animals for growth, and the oxygen necessary for combustion.

Source: SEEA 2.31

Efficiency

Efficiency (of production processes)

Efficiency refers to the degree to which a production process reflects 'best practice', either in an engineering sense ('technical efficiency') or in an economic sense ('allocative efficiency').

- Full technical efficiency characterises a production process where the maximum possible output has been achieved, given a fixed set of inputs and given a certain technology.
- Full allocative efficiency prevails when the input-output combination is cost- minimising and/or profit maximising.

Source: Measuring Productivity - OECD Manual: Measurement of Aggregate and Industry-Level Productivity Growth, OECD, Paris, 2001. [http://www.oecd.org/dataoecd/59/29/2352458.pdf].

Environmental accounting

Environmental accounting refers to the combination of natural resource accounts, which consist of stock and flow accounts in physical terms, and the monetary valuation of these accounts. See "Integrated Environmental and Economic Accounting (SEEA)".

Source: SEEA

Environmental assets, see natural assets

Environmental impact

The term "environmental impact" refers to the direct effect (positive or negative) of socio-economic activities and natural events on the components of the environment.

The word "impact" here means any effect caused by a given activity on the environment including human health and safety, flora, fauna, soil, air, water, climate, landscape and historical monuments or other physical structures or the interaction among these factors; it also includes effects on cultural heritage or socio-economic conditions resulting from alterations to those factors.

Source: OECD, based on various sources (UNSD, Espoo Convention, EC)

Environmental impact assessment

An environmental impact assessment (EIA) is an analytical process or procedure that systematically examines the possible environmental consequences of the implementation of a given activity (projects, programmes and policies). The aim is to ensure that the environmental implications of decisions related to a given activity are taken into account before the decisions are made.
Source: OECD, based on various sources.

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.
Source: WRI

Environmental indicator

A parameter, or a value derived from parameters, which points to, provides information about, describes the state of a phenomenon/environment/area, with a significance extending beyond that directly associated with a parameter value. This definition points to two major functions of indicators:

- they reduce the number of measurements and parameters that normally would be required to give an exact presentation of a situation.

As a consequence, the size of an indicator set and the level of detail contained in the set need to be limited. A set with a large number of indicators will tend to clutter the overview it is meant to provide.

- they simplify the communication process by which the results of measurement are provided to the user.

Due to this simplification and adaptation to user needs, indicators may not always meet strict scientific demands to demonstrate causal chains. Indicators should therefore be regarded as an expression of "the best knowledge available".

Environmental indicators comprise all indicators in the Pressure-State-Response model, i.e. "indicators of environmental pressures", "indicators of environmental conditions" and "indicators of societal responses".
See also "Index" and "Parameter".
Source: OECD, 1993

Environmental input-output analysis

Environmental input-output analysis (or extended IOA) refers to the application of input-output techniques to the study of the relationships between the functioning of the socio-economic system and environmentally relevant variables, especially expressing the pressures exerted by production and consumption on the natural environment (material flows to and from the natural environment). The traditional input-output framework is extended for this purpose with the inclusion of the environmental variables, so as to allow their analysis.
Source: OECD.

Environmental performance indicator

Environmental performance indicators are individual and/or aggregated indicators of environmental conditions, environmental pressures and societal responses linked to the measurement of environmental achievements and to underlying drivers and country's specific conditions. Two broad categories of performance indicators are distinguished:

- Performance indicators linked to quantitative objectives (targets, commitments). Examples of such indicators include e.g. air emission trends relating to national or international targets, urban air quality relating to national standards;
- Performance indicators linked to qualitative objectives (aims, goals). These indicators generally address the concept of performance in two ways:
  - with respect to the eco-efficiency of human activities, linked to the notions of de-coupling, elasticities: e.g. emissions per unit of GDP, relative trends of waste generation and GDP growth, resource productivity; and
  - with respect to the sustainability of natural resource use: e.g. intensity of the use of forest resources, intensity of the use of water resources;

Source: OECD, 1993

Environmental requirements of products

The total direct and indirect uses of natural resources or residual emissions generation; environmental requirement is calculated using input-output techniques.
Source: SEEA 4.119

Environmental pressures, see Pressure - State - Response (PSR) model

Environmental resources, see Natural resources

Environmental space

The annual total consumption of natural resources to which each individual is "entitled", based on the capacity of the natural environment.
Source: Eurostat, 2001

Factor 4/ Factor 10

The idea behind Factor 4 or Factor 10 is that natural resources can be used more efficiently in all domains of daily life, either by generating more products, services and quality of life from the available resources, or by using less resources to maintain the same standard. Factor 4 and factor 10 are not meant as fixed numerical values. They are normative guidelines that are appraised by physical input factors (energy, material, water, land) as well as a number of qualitative factors.

Factor 4: This is an objective whereby the input of natural resources, raw materials and energy in each unit of production is to be reduced to one quarter of its current level in the medium term, over the next 20 to 30 years. It refers to a hypothetical fourfold increase in 'resource productivity', brought about by simultaneously doubling wealth and halving resource consumption ("*FACTOR FOUR - Doubling Wealth, Halving Resource Use*" Ernst Ulrich v. Weizsäcker, Amory Lovins and L. Hunter Lovins, Earthscan Publications Ltd., London, 1997).

Factor 10: This is an objective whereby the input of natural resources, raw materials and energy in each unit of production is to be reduced to one tenth of its current level in the long term, over the next 30 to 50 years.
Source: Wuppertal Institut (http://www.wupperinst.org/FactorFour), Eurostat, 2001.

Final consumption

Final consumption consists of goods and services used up by individual households or the community to satisfy their individual or collective needs or wants.
Source: SNA 1.49

Goods

Goods are physical objects for which a demand exists, over which ownership rights can be established and whose ownership can be transferred from one institutional unit to another by engaging in transactions on markets; they are in demand because they may be used to satisfy the needs or wants of households or the community or used to produce other goods or services.
Source: SNA 6.7.

Hidden (material) flows

The term 'hidden flow' refers to a concept used in economy-wide material flow analysis and accounting. It is used to designate (i) the movements of unused materials associated with the extraction of raw materials from natural resources, both nationally and abroad, intended for use in the national economy; and (ii) the indirect flows of materials such as pollution or waste that occur upstream in a production process but that are not physically embodied in the product itself. The word "hidden" reflects the fact that these flows usually do not appear in traditional economic accounting. Since indirect flows are often difficult to estimate, the term "hidden flows" is sometimes used as a synonym for "unused extraction".
Source: OECD (based on Eurostat 2001)

Hybrid flow accounts

A single matrix account containing both national accounts in monetary terms and physical flow accounts showing the absorption of natural resources and ecosystem inputs and the generation of residuals.
Source: SEEA 4.4

Hybrid input-output tables

A symmetric table where the SNA monetary input output table is combined with the corresponding physical input output table.
Source: SEEA 4.9

Hybrid supply and use tables

A particular form of matrix accounting which includes in the same table monetary flows relating to products and physical flows relating to natural resources, ecosystem inputs and residual generation.
Source: SEEA 2.69 & 4.8

Index

A set of aggregated or weighted parameters or indicators.
Source: OECD, 1993

Indirect (material) flows

The term "indirect flows" is used to designate the flows of materials that (i) are needed for the production of a product, (ii) have occurred up-stream in the production process, and (iii) are not physically embodied in the product itself. Indirect flows take into account the life-cycle dimension of the production chain, and encompass both used and unused materials.

In material flow accounting, indirect materials flows refer to flows of materials that are associated to direct flows, but that do not physically cross the boundary of the economic system (i.e. the national economy in the case of national economy-wide material flow accounts). They measure the mass (weight) of the 'cradle to border' material requirements necessary to make a product available at the border of a system either as an input or an output, minus the mass (weight) of the product itself. Such indirect flows are sometimes called "ecological rucksack".

In economy-wide material flow accounting (i.e. Eurostat, 2001) where the national economy is considered as a whole, "indirect flows" refer to upstream flows associated to imports and exports, i.e. flows that indirectly cross the boundary between the domestic economy and the rest of the world economy.

- On the input side, indirect flows are defined as the upstream material input flows that are associated to imports but are not physically imported. This includes indirect flows of used materials (i.e. the raw material equivalents of imported products minus the weight of the imported product) as well as indirect flows of unused materials (i.e. the unused extraction associated to imported products). Indirect input flows and their environmental consequences occur in countries from which the imports originate.
- On the output side, indirect flows are defined as the upstream material input flows that are associated to exports but are not physically exported. This includes indirect flows of used materials (i.e. the raw material equivalents of exported products minus the mass (weight) of the exported product itself), and indirect flows of unused materials (i.e. the unused extraction associated to exported products). Indirect output flows and their environmental consequences take place in the country for which the accounts are set up, i.e. in the domestic system.

In a PIOT framework, where the economy is further disaggregated into sub-systems (branches of production and categories of final use), the term "indirect flows" can be used to designate indirect material or product flows within the economy, i.e. upstream flows associated to deliveries that indirectly cross the boundary between branches of production and categories of final use.
Source: OECD (based on Eurostat 2001)

Input-output table

An input-output table is a means of presenting a detailed analysis of the process of production and the use of goods and services (products) and the income generated in that production; they can be either in the form of (a) supply and use tables or (b) symmetric input-output tables.
Source: SNA 15.1 and 15.8 [2.211, 15.2]

Integrated product policy (IPP)

Integrated product policy (IPP) is a management approach that seeks to minimise the negative environmental impacts from products "from cradle to grave", by looking at all phases of a product's life-cycle and by taking action where it is most effective.
Source: OECD

Intermediate consumption

Intermediate consumption consists of the value of the goods and services consumed as inputs by a process of production, excluding fixed assets whose consumption is recorded as consumption of fixed capital; the goods or services may be either transformed or used up by the production process.
Source: SNA 6.147

Life Cycle Assessment or Analysis (LCA)

A method of assessing the material requirements and potential environmental pressures of a product or a service over its entire life cycle. The life cycle generally means the time between manufacturing the product and ultimately disposing of it. The International Organisation for Standardisation (ISO), a world-wide federation of national standards bodies, has standardised this framework within the series ISO 14040 on LCA. Life cycle assessments (LCA) are based on life cycle inventories.
Source: OECD (based on Eurostat, 2001)

Life-cycle

Life-cycle is a concept used in life cycle analyses and material flow analyses to determine the environmental burden of products and services from "cradle-to-grave", i.e. from the source (raw material- or primary energy extraction) through the use phase to the "sink" (e.g. waste treatment, or recycling) and to include the materials needed for the construction, all transports and auxiliary inputs as well. The links of all processes which contribute to a life-cycle are called process chain.
Source: GEMIS Glossary, www.oeko.de

Mass balance

In environmental accounting, a mass balance is a specific supply and use table where different physical flows for products and/or residuals are expressed in a common specific unit; for example timber, forests products and wood waste converted into 'dry-matter tonnes of wood'.
Source: SEEA 3.189

Mass or material balance principle

The mass balance principle is founded on the first law of thermodynamics (called the law of conservation of matter), which states that matter (mass, energy) is neither created nor destroyed by any physical process. When applied to material flow analysis and accounts, this leads to the following accounting identity:
natural resource extraction + imports = residual output + exports + net addition to man-made stocks
i.e. the sum of material inputs into a system equals the sum of its material outputs, thereby comprising the materials accumulated as changes in stocks.
Source: OECD.

Material (and energy) balances

Accounting tables that provide information on the material input into an economy delivered by the natural environment, the transformation and use of that input in economic processes (extraction, conversion, manufacturing, consumption) and its return to the natural environment as residuals (wastes). The accounting concepts involved are founded on the mass balance principle, i.e. the first law of thermodynamics, which states that matter (mass, energy) is neither created nor destroyed by any physical process.
Source: UNSD, Environment Glossary

Material consumption

Material consumption refers to the materials consumed in an economy whether for intermediate or for final consumption.
Source: OECD.

Material efficiency

The term "material efficiency" denotes the efficiency with which material resources are used in the economy or in a production process. It is often used as a synonym for material productivity.
Source: Economy-wide material flow accounts and derived indicators – A methodological guide, Eurostat, 2001

Material efficiency indicators

Material efficiency indicators are constructed by relating economic output indicators (such as GDP or value added) to economy-wide or sectoral MF indicators, thus providing information about the material productivity or intensity of the economy or economic activity sectors.
Source: OECD.

Material extraction

The extraction of materials from the environment (i.e. from natural resources) on purpose and by means of technology for use in human activities.
Gross material extraction refers to all materials extracted, moved or disturbed by economic activities on purpose and by means of technology, including those materials that remain unused in the environment or return to the environment immediately after removal from their natural site. In material flow accounting, gross material extraction comprises "used" extraction and "unused" extraction.
Net material extraction refers to the materials extracted that physically enter the economic system as inputs for further processing or consumption. In material flow accounting, net material extraction is called "used extraction".
Source: OECD.

Material Flow Accounts (MFAcc)

Material flow accounts (MFAcc) are methodically organised accounts in physical units (usually in tonnes) that quantify the flows of different types of materials into, out of and possibly within a given system at different levels of detail and completeness, and by making reference to the material balance principle. They provide information on the material input from the environment into the system (e.g. resources extracted or harvested from the surrounding natural environment or imported from other systems), the transformation and use of that input in the system (from material production to final consumption) and the material outputs of the system in the form of returns to the environment as residuals (waste, pollutants) or in the form of exports to other systems.

Material flow accounts are part of environmental accounting and of the physical flow accounts family as described in the System of integrated Environmental and Economic Accounting (SEEA). An important feature of MFAcc is that they track both direct flows (i.e. flows of materials physically entering the economic process) and indirect and unused flows (i.e. flows of materials not entering the economic process, but associated to resource exploitation and to the up-stream production process of a product and of relevance from an environmental point of view).

The system to which the accounts apply is usually an economic system with its production and consumption activities, and its interactions with the surrounding environment and with other economic systems and their environment. It is these interactions that are of interest to MFAcc. The materials are recorded in physical units (usually tonnes). MFAcc can be established at various levels of scale (world regions, whole national economy, branches of production, firms, municipalities, etc.) and can be applied to materials at various levels of detail (all materials, groups of materials, individual materials or substances).

Complete Material Flow Accounts

The term "complete" is used to qualify MFAcc that cover the entire range of materials exchanged at the boundary of the system studied, whatever the level of detail of the analysis is (individual materials or substances, groups of materials, aggregate amount of materials).
Source: OECD.

Economy-wide Material Flow Accounts (EW-MFAcc)

The term "economy-wide" is used to qualify MFAcc that cover the national economy as a whole (black box), and that track the physical flows of the entire range of natural resources and materials exchanged at the boundary of the national economy. An important feature of EW-MFAcc is that they are complete as regards the materials covered, with the exception of water, and that all materials are recorded in a common physical unit. They thus usually provide a fairly detailed database that can be used to provide both an aggregate overview of annual material inputs and outputs of an economy, and a basis for in-depth MF studies and analyses.
Source: OECD (based on Eurostat 2001)

National Material flow accounts

The term "national" is used to qualify MFAcc that cover the national economy (i.e. the production and consumption activities taking place on a country's economic territory) as a whole or broken down into its components at any desired level of breakdown (e.g. economic activities and final use functions). National MFAcc can be applied to materials at various levels of detail (all materials, groups of materials, individual materials or substances).
Source: OECD.

See also "Physical Input-Output Tables (PIOTs)" and "Substance Flow Analysis".

Material Flow Analysis (MFA)

Material flow analysis (MFA) refers to the monitoring and analysis of physical flows of materials into, through and out of a given system (usually the economy) through the process chains, through extraction, production, use, recycling and final disposal. MFA is generally based on methodically organised accounts in physical units (Material flow accounts). It helps identify waste of natural resources and materials in the economy which would otherwise go unnoticed in conventional economic monitoring systems.

The term MFA is used in a generic way to designate a family of tools encompassing different types of accounts, indicators and evaluation methods at different levels of ambition, detail and completeness. MFA can be applied to a wide range of economic, administrative or natural entities at various levels of scale (world regions, whole economy, industries, firms, plants, territories, cities, river basins, eco-zones, etc.) and can be applied to materials at various levels of detail (individual materials or substances, groups of materials, all materials).
Source: OECD.

Material flow indicators

Material flow indicators are defined as quantitative measures, which point to, inform about, describe, the characteristics of material flows and material resource use and which have a meaning or a significance that goes beyond that directly associated with the underlying statistics.
Source: OECD.

Material input

Material inputs refer to the flows of materials entering a system. When applied to the economic system, material inputs refer to the materials mobilised or used for sustaining economic activities, including the production of export goods and services. This includes the flows of materials that are extracted from the environment and that physically enter the economy or the system for further processing or direct consumption and the flows of materials imported from abroad or from other systems.
Source: OECD.

Material Input Per Service (MIPS)

MIPS estimates the overall consumption of natural resources or materials by a product or a service over its whole life-cycle from cradle to cradle (extraction, production, use, disposal/recycling) and is seen as a proxy for the overall potential environmental burden of a product or a service. The MIPS indicator is usually applied at the micro-level, where it focuses on specific products and services. It accounts for the cumulated primary resource requirements for the categories (i) abiotic raw materials, (ii) biotic raw materials, (iii) soil and earth movements, (iv) water and air.

Source: Wuppertal Institute

Material output

Material outputs refer to the flows of materials leaving a system. When applied to the economic system, material outputs refer to the material outflows related to production and consumption activities of a given country or entity. They account for those materials that have been used in the economy or the system and are subsequently leaving it either in the form of emissions and waste, or in the form of exports to other systems.
Source: OECD.

Material productivity

Material productivity makes reference to the effectiveness with which an economy or a production process is using materials extracted from natural resources. It can be defined with respect to:

(i) the economic-physical efficiency, i.e. the money value added of outputs per mass unit of material inputs used. This is also the focus when the aim is to decouple value added and material consumption.

(ii) the physical or technical efficiency, i.e. the amount of material input required to produce a unit of output, both expressed in physical terms (e.g. iron ore inputs for crude steel production or raw material inputs for the production of a computer, a car, batteries). The focus is on maximising the output with a given set of inputs and a given technology or on minimising the inputs for a given output.

(iii) the economic efficiency, i.e. the money value of outputs relative to the money value of inputs. The focus is on minimising material input costs.

The term also designates an indicator that reflects the output or value added generated per unit of materials used. This is typically a macro-economic concept that can be presented alongside labour or capital productivity. It should be noted that the term "resource productivity" is often used to designate material productivity though the latter does not cover all resources (e.g. water is usually not included).
Source:OECD, Eurostat, 2001

Raw material productivity

Effectiveness with which an economy or a production process is using raw materials. Raw material productivity is defined as the ratio between gross value added and the sum of raw materials extracted in the country (considering the portion actually used) and imported goods in the form of raw materials (GDP/RMI). It can be calculated separately for biotic and abiotic materials, i.e. for materials that stem from renewable natural resource stocks (e.g. those related to agricultural or forestry products) and for materials that stem from non-renewable natural resource stocks (e.g. metal ores and metals).
Source: German Environment Barometer, DESTATIS

Materials or material resources

The term "materials" or "material resources" designates the usable materials or substances (raw materials, energy) produced from natural resources. These usable "materials" include energy carriers (gas, oil, coal), metal ores and metals, construction minerals and other minerals, soil and biomass.

In the context of Material Flow Analysis and Accounting, the term "materials" is used in a very broad sense so as to record all material related flows at all relevant stages of the material cycle. It designates materials from renewable and non-renewable natural resource stocks that are used as material inputs into human activities and the products that embody them, as well as the residuals arising from their extraction, production and use (such as waste or pollutant emissions to air, land, water) and the ecosystem inputs required for their extraction, production and use (such as nutrients, carbon dioxide required by plants and animals for growth and the oxygen necessary for combustion).
Source: OECD.

Composite (or compound) material

A material combining two or more materials, each having its own characteristics, in order to provide the composite with useful properties for specific applications.

Material system analysis (MSA)

Material system analysis (MSA) is based on individual material flow accounts. It focuses on selected raw materials or semi-finished products at various levels of detail and application (e.g. cement, paper, iron and steel, copper, plastics, timber, water) and considers life-cycle-wide inputs and outputs. It applies to materials that raise particular concerns as to the sustainability of their use, as to the security of their supply to major economic activity sectors, and/or the environmental consequences of their production and consumption.
Source: OECD. (based on Moll and Femia, 2005)

Metallic mineral reserves, see Mineral and energy reserves

MFA

The abbreviation MFA stays for the term "material flow analysis"; it is used in a generic way and encompasses all tools of the MFA family, including accounts, indicators and analytical tools. See Material Flow Analysis.

Source: OECD.

MFAcc

The abbreviation MFAcc stays for the terms "material flow accounts" or "material flow accounting"; it covers all types of accounts that quantify the physical flows of material resources through a system. See Material Flow Accounting.
Source: OECD.

Mineral and energy reserves

Mineral and energy reserves refer to subsoil deposits of fossil fuels, metallic minerals and non-metallic minerals. In environmental accounting (i.e. the SEEA), these include not only the proven reserves but also probable, possible potential and speculative resources.
Source: based on SEEA 7.147 &7.43

Metallic mineral reserves

Metallic mineral reserves consist of ferrous and non-ferrous metal ore deposits.
Source: (AN.2122)

Non-metallic mineral reserves

Non-metallic mineral reserves consist of stone quarries and clay and sand pits; chemical and fertiliser mineral deposits; salt deposits; deposits of quartz, gypsum, natural gem stones, asphalt and bitumen, peat and other non-metallic minerals other than coal and petroleum.
Source: SNA / (AN.2123)

NAMEA, National Accounting Matrix including Environmental Accounts

"National Accounting Matrix with Environmental Accounts" A matrix presentation of monetary accounts augmented by the input of natural resources, ecosystem inputs and residual outputs in physical terms. It is synonymous with hybrid supply and use tables.
Source: SEEA 2.73

Natural assets

Natural assets are assets of the natural environment. These consist of biological assets (produced or wild), land and water areas with their ecosystems, subsoil assets and air. Natural assets include natural economic assets and natural non-economic assets.

In environmental accounting (the SEEA), natural assets are also referred to as environmental assets and stay as a synonym for natural capital. They designate naturally occurring entities that provide environmental "functions" or services. They are defined in a broad sense: they cover all assets including those which have no economic values, but bring indirect uses benefits, options and bequest benefits or simply existence benefits which cannot be translated into a present day monetary value.

In economic accounting, the term "environmental assets" is defined in a narrower sense than in environmental accounting (the SEEA). It corresponds to tangible non-produced assets. They are assets that occur in nature and over which ownership rights have been established and which provide economic benefits to their owner. Environmental assets over which ownership rights have not, or cannot, be established, such as the high seas or air, are excluded because they do not qualify as economic assets.
Source: OECD, based on SEEA 7.92 and SNA 13.53

Natural economic assets

Natural economic assets are non-produced natural assets that function as providers of natural resource inputs into production.

Natural non-economic assets

Natural non-economic assets are non-produced natural assets that do not function as providers of natural resource inputs into production but as providers of environmental services of waste absorption, ecological functions such as habitat or flood and climate control, and other non-economic amenities such as health and aesthetical values.
Source: OECD, based on UNSD, Glossary of Environment Statistics, 1997.

Natural capital

In environmental accounting, the term "natural capital" is used to designate all natural assets, also called environmental assets, whether they are economic assets or not. Natural capital is generally considered to comprise three principal categories: natural resource stocks, land and ecosystems. All are considered essential to the long-term sustainability of development for their provision of "functions" to the economy, as well as to mankind outside the economy and other living beings. See resource functions, service functions, sink functions of the environment.
Source: SEEA 1.23

Natural Resource Accounting (NRA)

An accounting system that monitors the stocks and flows of natural assets, comprising biological assets (produced or wild), subsoil assets (proved reserves); and water and land with their aquatic and terrestrial ecosystems. The term is used frequently in the sense of physical accounting, i.e. accounts expressed in physical units, as distinguished from monetary (environmental) accounting.
Source: OECD, based on Natural Resource Accounts – Taking Stock in OECD countries, OECD, 1994, and UNSD, Environment Glossary

Natural resources

The term "natural resources" designates renewable and non-renewable resource stocks that are found in nature (mineral resources, energy resources, soil resources, water resources and biological resources). Natural resources are commonly divided into non-renewable and renewable resources:

Renewable natural resources

Renewable natural resources are resources from renewable natural stocks that, after exploitation, can return to their previous stock levels by natural processes of growth or replenishment. Conditionally renewable resources are those whose exploitation eventually reaches a level beyond which regeneration will become impossible. Such is the case with the clear-cutting of tropical forests. Examples of renewable resources include timber from forest resources, freshwater resources, land resources, wildlife resources such as fish, agricultural resources.
Source: OECD, and UNSD, Environment Glossary

Non-renewable natural resources

Non-renewable natural resources are exhaustible natural resources whose natural stocks cannot be regenerated after exploitation or that can only be regenerated or replenished by natural cycles that are relatively slow at human scale. Examples include metals and other minerals such as industrial and construction minerals, and fossil energy carriers, such as oil.
Source: OECD, and UNSD, Environment Glossary

In environmental accounting, the term "natural resources" is used to designate stocks of natural resources. It is defined as the natural assets occurring in nature that can be used for economic production or consumption, i.e. natural economic assets. Together with land and ecosystems, stocks of natural resources form what is called the natural capital.

Natural resource stocks are the naturally occurring assets that provide use benefits through the provision of raw materials and energy used in economic activity (or that may provide such benefits one day) and that are subject primarily to quantitative depletion through human use. They are subdivided into four categories: mineral and energy resources, soil resources, water resources and biological resources. Stocks of mineral and energy resources are also called mineral and energy reserves.
Source: OECD, based on SEEA 7.42 / EA.1

Flows of natural resources

In environmental accounting, flows of natural resources are defined as natural resources that are drawn from the natural environment into the economy and become transformed into products; or that are harvested from the natural environment for own account use, for example fuel wood collected by households, the extraction of construction materials and water.
Source: based on SEEA 3.88

Net Additions to Stock (NAS)

Net Additions to Stock (NAS) is a variable used in material flow accounting. NAS reflect the 'physical growth of the economy'. The term refers to the balance between:

- gross additions to stock, i.e. the mass (weight) of new construction materials used in buildings and other infrastructure, and of materials incorporated into new durable goods (such as cars, industrial machinery, and household appliances), and
- removals from stock, i.e. the mass (weight) of old materials removed from stock as buildings are demolished and durable goods disposed of. These decommissioned materials, if not recycled, are accounted for in domestic processed output (DPO).

Source: OECD. (based on Eurostat, 2001)

Non-metallic mineral reserves, see mineral and energy reserves

Parameter

A property that is measured or observed.
Source: OECD, 1993

Physical flow accounts

The physical flow accounts presented in [SEEA] are based around the distinction between natural resources, ecosystem inputs, products and residuals. Natural resources and ecosystem inputs enter the economy;

residuals eventually leave it. Economic activity itself is concerned with the production and consumption of goods and services (products). All natural resources and ecosystem inputs absorbed by the economy are converted into products by one means or another. All physical products eventually return to the environment as residuals. It is the process in between, when products circulate within the economy which is of interest for economic accounting since this is the point in the cycle when monetary values can be associated with the flows.
Source: SEEA 4.7

Physical Input-Output Tables (PIOTs)

A Physical Input-Output Table (PIOT) is a symmetric table that shows physical flows (for all materials or a subset of materials) from the environment or rest of the world to the economy, within the economy and from the economy to the rest of the world.
Source: SEEA 3.210

PIOTs provide a comprehensive description of the flows of materials and energy between the environment and economy as well as within the economy, distinguishing not only categories of materials but also branches of production.
Source: OECD.

Physical supply and use tables

Supply and use tables are accounts in physical units in the form of matrices that record the flows of natural resources, residuals, products and eco-systems inputs according to origins (supply) and destinations (uses).
Source: SEEA 3.96

Physical Trade Balance (PTB)

Physical Trade Balance (PTB) is a variable used in material flow accounting. It measures the physical trade surplus or deficit of an economy. In economy-wide material flow accounting, PTB equals imports minus exports. Physical trade balances may also be calculated for indirect flows associated to Imports and Exports.
Source: OECD. (based on Eurostat, 2001)

Pollutant Release and Transfer Registers (PRTRs)

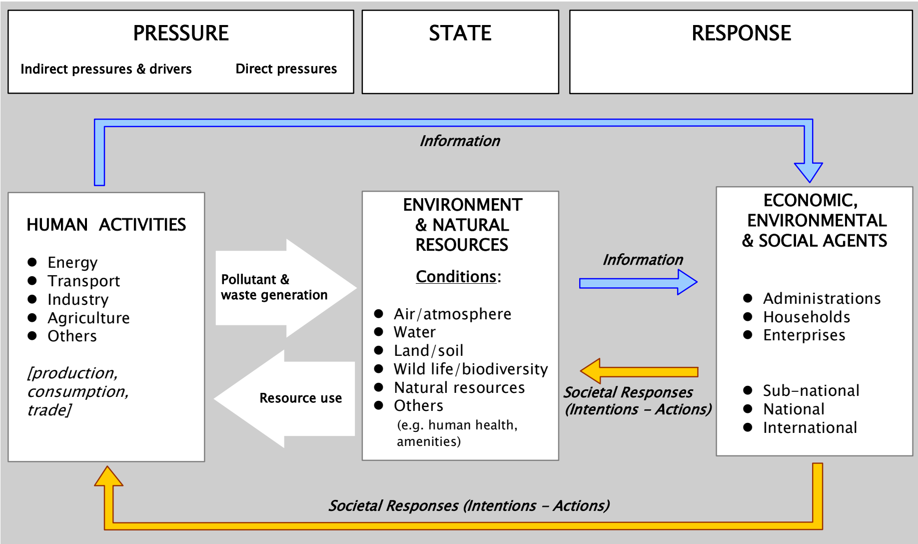
A Pollutant Release and Transfer Register (PRTR) is an environmental database or inventory of potentially harmful chemicals and/or pollutants released or transferred to the environment (air, water, land) from a variety of sources, or transferred off-site for treatment. A PRTR also consists of reports about specific species such as benzene, methane or mercury as contrasted with broad categories of pollution such as volatile organic compounds, greenhouse gases or heavy metals.
Source: OECD, based on Pollutant Release and Transfer Registers (PRTRs) – Guidance Manual for Governments, OECD, 1996, Resource Compendium of PRTR Release Estimation Techniques, 2005

Pressure-State-Response (PSR) model

The PSR model has been developed by the OECD as a framework to structure its work on environmental policies and reporting, building on a model originally developed by A. Friend and D. Rapport. The PSR model considers that: human activities exert pressures on the environment and affect its quality and the quantity of natural resources ("state"); society responds to these changes through environmental, general economic and sectoral policies, and through changes in awareness and behaviour ("societal response").

The PSR model highlights these cause-effect relationships, and helps see environmental, economic, and other issues as interconnected. It is neutral in the sense that it shows which linkages exist and not whether these have negative or positive impacts. It is recognised that this should not obscure the view of more complex relationships in ecosystems, and in environment-economy and environment-social interactions.

The PSR model can easily be adjusted to account for greater details or for specific features. An example of an adjusted version is the Driving force-Pressure-State-Impact-Response (DPSIR) model used by the European Environment Agency (EEA).



Source: OECD

Environmental pressures

In the PSR model, environmental pressures are pressures from human activities exerted on the environment, including natural resources. The term "pressures" is used to designate proximate or direct pressures (i.e. pressures directly exerted on the environment through the use of natural resources and the discharge of pollutants and waste materials), as well as underlying or indirect pressures (i.e. human activities which lead to proximate environmental pressures and trends and patterns of environmental significance) sometimes referred to as environmental driving forces.
Indicators of environmental pressures are closely related to production and consumption patterns; they often reflect emission or resource use intensities, along with related trends and changes over a given period. They can be used to show progress in decoupling economic activities from related environmental pressures, or in meeting national objectives and international commitments (e.g. emission reduction targets).

Environmental conditions

In the PSR model, environmental conditions relate to the quality of the environment and the quality and quantity of natural resources. The term "environmental conditions" is used to designate ecosystems and natural environment conditions as well as quality of life and human health aspects. As such they reflect the ultimate objective of environmental policies.
Indicators of environmental conditions are designed to give an overview of the situation (the state) concerning the environment and its development over time. Examples of indicators of environmental conditions are: concentration of pollutants in environmental media, exceedance of critical loads, population exposure to certain levels of pollution or degraded environmental quality and related effects on health, the status of wildlife and ecosystems and of natural resource stocks. In practice, measuring environmental conditions can be difficult or very costly. Therefore, environmental pressures are often measured instead as a substitute.

Societal responses

In the PSR model, societal responses show the extent to which society responds to environmental concerns. They refer to individual and collective actions and reactions, intended to:

- mitigate, adapt to or prevent human-induced negative effects on the environment;
- halt or reverse environmental damage already inflicted;
- preserve and conserve nature and natural resources.

Examples of indicators of societal responses are environmental expenditure, environment-related taxes and subsidies, price structures, market shares of environmentally friendly goods and services, pollution abatement rates, waste recycling rates, enforcement and compliance activities. In practice, indicators mostly relate to abatement and control measures; those showing preventive and integrative measures and actions are more difficult to obtain.
Source: OECD

Productivity

Productivity is commonly defined as a ratio of a volume measure of output to a volume measure of input use. While there is no disagreement on this general notion, a look at the productivity literature and its various applications reveals that there is neither a unique purpose for measuring productivity nor a single measure. Productivity is generally measured within the SNA production boundary.

Overview of the main productivity measures

Type of input measure / Type of output measure	*Labour*	*Capital*	*Capital and labour*	*Capital, labour & intermediate inputs (energy, materials, services)*
Gross output	Labour productivity (based on gross output)	Capital productivity (based on gross output)	Capital-labour MFP (based on gross output)	KLEMS multi-factor productivity
Value-added	Labour productivity (based on value-added)	Capital productivity (based on value-added)	Capital-labour MFP (based on value-added)	–
	Single factor productivity measures		***Multi factor productivity (MFP) measures***	

Source: Measuring Productivity - OECD Manual: Measurement of Aggregate and Industry-Level Productivity Growth, OECD, Paris, 2001. [http://www.oecd.org/dataoecd/59/29/2352458.pdf].

The terms productivity and efficiency refer to different but related concepts. Productivity relates the quantity of output produced to one or more inputs used in the production of the output, irrespective of the efficiency of their use.

Products or Commodities

Products, also called "goods and services", are the result of production; they are exchanged and used for various purposes: as inputs in the production of other goods and services, as final consumption or for investment. The term "commodities" can be used as a synonym for "products".
Source: SNA 2.49

Products are goods and services produced within the economic sphere and used within it, including flows of goods and services between the national economy and the rest of the world.
Source: SEEA 2.31

Commodities are goods and services normally intended for sale on the market at a price that is designed to cover their cost of production. Includes all goods and services produced by industries, all imported goods and services except direct purchases abroad by government and households, and that part of the gross output of producers of government services and a private non- profit services to households which is sold on the conditions, characteristic of sales of commodities.
Source: OECD Economic Outlook: Sources and Methods

Primary commodities: Food and live animals, beverages and tobacco, excluding manufactured goods; crude materials, inedible, excluding fuels, synthetic fibres, waste and scrap; mineral fuels, lubricants and related materials, excluding petroleum products; animal and vegetable oils, fats and waxes.
Source: SNA

Raw materials

Raw materials are natural resources which are converted into useful primary materials. Examples are ores (for metals), minerals (e.g. chalk, gravel, sand, stones), air and water, but also oil, natural gas, coal and biomass if they are used as matter (e.g. construction materials, lubricants).
Source: Global Emission Model for Integrated Systems (GEMIS) Glossary, Öko Institut, www.oeko.de

Primary raw materials

Primary raw materials or virgin raw materials are basic natural materials that are extracted from the ground or harvested and processed into new materials or products. For example, bauxite is the raw material that is processed into aluminium, petroleum for plastics manufacture, iron ore for steel manufacture and wood pulp for paper manufacture
Source: Planet Ark, Reuters Daily World Environment News, Glossary [http://www.planetark.com]

Secondary raw materials

Secondary raw materials are materials that have been manufactured and used at least once, and that are recovered (from the waste stream or from used products) to be used again for further manufacturing.
Source: OECD, based on Environmental Terms Glossary, US Navy

Raw material equivalents

"Raw material equivalents" is a term used in material flow analysis and accounting. It designates the used extraction of raw materials that was needed for the production of a good or service, including the mass of the product itself. Raw material equivalent conversion factors can be used as a basis for expressing material flows in standardised measurement units.
Source: OECD

Recovery

Recovery is defined as any waste management operation that diverts a material from the waste stream and which results in a certain product with a potential economic or ecological benefit. Recovery mainly refers to the following operations:

- material recovery, i.e. recycling (see below);
- energy recovery, i.e. use as a fuel;
- biological recovery, e.g. composting;
- re-use of materials diverted from the waste stream.

Source: OECD

Recovery means any of the operations R1-R13 specified in Appendix 5B to the OECD Decision of the Council Concerning the Control of Transboundary Movements of Wastes Destined for Recovery Operations (wording identical to that of Annex IV.B of the Basel Convention):

R1 Use as a fuel (other than in direct incineration) or other means to generate energy
R2 Solvent reclamation/regeneration
R3 Recycling/reclamation of organic substances which are not used as solvents
R4 Recycling/reclamation of metals and metal compounds
R5 Recycling/reclamation of other inorganic materials
R6 Regeneration of acids or bases
R7 Recovery of components used for pollution abatement
R8 Recovery of components from catalysts
R9 Used oil re-refining or other reuses of previously used oil
R10 Land treatment resulting in benefit to agriculture or ecological improvement
R11 Uses of residual materials obtained from any of the operations numbered R1-R10
R12 Exchange of wastes for submission to any of the operations numbered R1-R11
R13 Accumulation of material intended for any operation in Appendix 5.B

Source: C(2001)107/FINAL, OECD, 2001. [http://webdomino1.oecd.org/horizontal/oecdacts.nsf].

Recyclable materials

Materials that have the potential for being recycled.

Recycling (or material recovery)

Recycling is defined as any reprocessing of material in a production process that diverts it from the waste stream, except use as fuel. It includes both reprocessing as the same type of product, i.e. of an identical nature, and reprocessing as products of similar nature but for different purposes. Also called "material recovery".

Examples of recycling include industrial melting of one way glass bottles for use in new bottles, recycling of collected newspapers for production of sanitary paper products, aerobic or anaerobic treatment of separately collected organic household waste to produce agricultural soil.

Source: OECD, based on Strategic Waste Prevention: OECD Reference Manual, ENV/EPOC/PPC(2000)5/FINAL, OECD, 2000. [http://www.oecd.org/waste].

In environmental accounting, recycling is defined as the re-introduction of residual materials into production processes so that they may be reformulated into new products.

Source: SEEA 3.51

Remanufactured goods

Goods that have been manufactured and used at least once, and that have subsequently been disassembled and have undergone further or new manufacturing that makes them fit for being used again.

Source: OECD.

Remanufacturing (or product recovery)

Remanufacturing is defined as any further or new manufacturing of a product that has been used at least once to make it fit for being used again.

Source: OECD.

Renewable natural resources, see Natural resources

Residuals

"Residuals" is a generic term used to designate all unwanted waste materials in solid, liquid and gaseous form resulting from economic activity. Residuals encompass (solid) waste and pollutants. Residuals generally have no economic value and may be recycled, stored within the economy or released into the environment.

Source: OECD, based on SEEA 2.26 &2.31

Resource efficiency

There is no commonly agreed upon definition of resource efficiency. It is understood to refer to the economic efficiency and the environmental effectiveness with which an economy or a production process is using natural resources. It is also understood to contain both a *quantitative* dimension (e.g. the quantity of output produced with a given input of natural resources) and a *qualitative* dimension (e.g. the environmental impacts per unit of output produced with a given natural resource input).

Resource functions of the environment (of natural capital)

The functions whereby the environment provides natural resources that are used as inputs in the economy and converted into economic goods and services (e.g. mineral deposits, timber from natural forests, deep sea fish).
Source: OECD

The capacity of natural capital to provide natural resources which can be drawn into the economy to be converted into goods and services for the benefit of mankind.
Source: SEEA 1.23

Resource management

Integrated process of information gathering, analysis, planning, decision-making, allocation of resources and formulation and enforcement of regulations by which the management authorities control the present and future behaviour of interested parties, in order to ensure the continued productivity of the resources.
Source: UNSD, Environment Glossary

Resource productivity

Resource productivity refers to the effectiveness with which an economy or a production process is using natural resources. It can be defined with respect to:

(i) the economic-physical efficiency, i.e. the money value added of outputs per mass unit of resource inputs used. This is also the focus when the aim is to decouple value added and resource consumption.

(ii) the physical or technical efficiency, i.e. the amount of resources input required to produce a unit of output, both expressed in physical terms (e.g. iron ore inputs for crude steel production or raw material inputs for the production of a computer, a car, batteries). The focus is on maximising the output with a given set of inputs and a given technology or on minimising the inputs for a given output.

(iii) the economic efficiency, i.e. the money value of outputs relative to the money value of inputs. The focus is on minimising resource input costs.

The term also designates an indicator that reflects the output or value added generated per unit of resources used. This is typically a macro-economic concept that can be presented alongside labour or capital productivity. Resource productivity would ideally encompass all natural resources and ecosystem inputs that are used as factors of production in the economy. The term is however often used as a synonym for material productivity.
Source:OECD.

Response indicators, see Pressure - State - Response (PSR) model

Re-use

Re-use is defined as any operation by which end of life products and equipment (e.g. electrical and electronic equipment) or their components are used again for the same purpose for which they were originally conceived or for an alternative purpose, with or without reconditioning. Also called product re-use.
Source: OECD, based on Strategic Waste Prevention: OECD Reference Manual, ENV/EPOC/PPC(2000)5/FINAL, OECD, 2000. [http://www.oecd.org/waste].

In environmental accounting, re-use is defined as the re-introduction of a residual material into a production (or consumption) process so that it is used as an input in its original form.
Source: SEEA 3.51

Sink functions of the environment (of natural capital)

The natural processes of absorbing or assimilating residuals (pollutants, waste) that are generated by production and consumption activities and discharged to the environment.
Source: OECD

The capacity of the environment to absorb the unwanted by-products of production and consumption; exhaust gases from combustion or chemical processing, water used to clean products or people, discarded packaging and goods no longer wanted.
Source: SEEA 1.23

Service functions of the environment (of natural capital)

The functions whereby the environment provides habitats for man and wildlife. Service functions include ecosystem services and amenity functions (recreational and leisure services, landscape services), as well as survival functions such as the provision of clean air or clean water or protection against UV rays.
Source: OECD

Substances

The term "substances" is used to designate 'pure' chemical elements or compounds (e.g. heavy metals, chlorinated chemicals, CO_2, lead, copper, cadmium).
Source: OECD.

Substance Flow Analysis (SFA)

Substance Flow Analysis (SFA) refers to the systematic monitoring and analysis of physical flows of selected substances or groups of substances within a given system. SFA quantifies the pathways of these substances within the system, i.e. the flows into, out of and through the system. It generally focuses on substances that have been identified to raise particular concerns as regards the environmental and health risks associated with their production and use (i.e. hazardous substances), but can also be applied to substances that have been identified to raise particular economic or trade related issues. SFA can be carried out at various levels of scale. It generally focuses on a geographically defined area or entity such as a company, town, region, farm, ecosystem, river basin, but can also applied to a country as whole.
Source: OECD.

Supply and use tables

Supply and use tables are matrices that record how supplies of different kinds of goods and services originate from domestic industries and imports and how those supplies are allocated between various intermediate or final uses, including exports.
Source: SNA 1.16

Sustainable resource use

A concept that builds on an integrated approach to natural resource management. It encompasses aspects linked to the economic efficiency and environmental effectiveness of resource use at the various stages of the production and consumption chain, as well as related social aspects. In other words, it aims at optimising the net benefits from resource use within the context of economic development, by:

- ensuring adequate supplies of renewable and non-renewable resources to support economic activities and economic growth,
- managing the environmental impacts associated with their extraction, processing and use to minimise adverse effects,
- maintaining non-commercial environmental services, and
- preventing natural resource degradation and depletion.

Source: OECD.

Sustainable materials management

Sustainable Materials Management is an approach to promote sustainable materials use, integrating actions targeted at reducing negative environmental impacts and preserving natural capital throughout the life-cycles of materials, taking into account economic efficiency and social equity. (working definition)
Source: OECD

System of Accounts

A statistical package made up of several accounts which are generally of the same form, seeking to present statistical information on some particular phenomenon in a consistent and systematic manner. In most cases some effort is made to present the accounts in the form of a balance.
Source: Economy-wide material flow accounts and derived indicators – A methodological guide, Eurostat, 2001

System of Integrated Environmental and Economic Accounting (SEEA 2003)

The System for integrated Environmental and Economic Accounting (SEEA) is a satellite system of the System of National Accounts (SNA) that comprises 4 categories of accounts:

- The first considers purely physical data relating to flows of materials and energy and marshals them as far as possible according to the accounting structure of the SNA. The accounts in this category also show how flow data in physical and monetary terms can be combined to produce so-called "hybrid" flow accounts. Emissions accounts for greenhouse gases are an example of the type included in this category.
- The second category of accounts takes those elements of the existing SNA, which are relevant to the good management of the environment and shows how the environment –related transactions can be made more explicit. An account of expenditures made by businesses, governments and households to protect the environment is an example of the accounts included in this category.
- The third category of accounts in the SEEA comprises accounts for environmental assets measured in physical and monetary terms. Timber stock accounts showing opening and closing timber balances and the related changes over the course of an accounting period are an example.
- The final category of SEEA accounts considers how the existing SNA might be adjusted to account for the impact of the economy on the environment. Three sorts of adjustments are considered; those relating to depletion, those concerning so-called defensive expenditures and those relating to degradation.

The SEEA was developed by the United Nations, in co-operation with the European Commission, the International Monetary Fund, the OECD and the World Bank, for the incorporation of environmental concerns (environmental costs, benefits and assets) in the national accounts. The SEEA is intended to be a system with global application and standards, suitable for all countries and all aspects of the environment.
Source: Handbook of National Accounting - Integrated Environmental and Economic Accounting, UN, EC, IMF, OECD, WB, 2003, [SEEA 1.35 sq.]

System of National Accounts (SNA)

The SNA is an international accounting framework consisting of a coherent, consistent and integrated set of macro-economic accounts, balance sheets and tables based on a set of internationally agreed concepts, definitions, classifications and accounting rules. It provides a comprehensive accounting framework within which economic data can be compiled and presented in a format that is designed for the purposes of economic analysis, and decision and policy making.

An organised system of social monitoring based on methodical accounts describing the scope of activities in the economy in monetary terms based on macroeconomic theory. A primary indicator derived from these accounts is the Gross Domestic Product (GDP) which indicates the magnitude of economic activity in monetary terms.
Source: Economy-wide material flow accounts and derived indicators – A methodological guide, Eurostat, 2001

Total (domestic) Material Input (TMI)

Total (domestic) Material Input (TMI) is a variable used in material flow accounting. In economy-wide material flow accounting TMI equals DMI plus unused domestic extraction.
Source: OECD (based on Eurostat, 2001)

Total Domestic Output (TDO)

Total Domestic Output (TDO) is a variable used in material flow accounting. TDO measures the total mass (weight) of material outputs to the domestic environment caused by economic activity, i.e. all material outputs to the environment whether used in production and consumption activities before or not. In economy-wide material flow accounting TDO equals DPO plus unused domestic extraction.
Source: OECD (based on Eurostat, 2001)

Total Material Consumption (TMC)

Total Material Consumption (TMC) is a variable used in material flow accounting. TMC measures the total mass (weight) of materials that are associated to the (apparent) material consumption of the domestic economic system, whatever their origin is (domestic, rest of the world). In economy-wide material flow accounting TMC equals TMR minus exports and their indirect flows.
Source: OECD (based on Eurostat, 2001)

Total Material Output (TMO)

Total Material Output (TMO) is a variable used in material flow accounting. TMO measures the total mass (weight) of materials that leave the economic system, whether used in production and consumption activities before or not, and whatever their destination is (domestic environment, rest of the world economy). In economy-wide material flow accounting TMO equals TDO plus exports.
Source: OECD (based on Eurostat, 2001)

Total Material Requirement (TMR)

Total Material Requirement (TMR) is a variable used in material flow accounting. TMR refers to the total 'material base' of an economic system (i.e. the total primary material requirements of production activities). TMR measures the total mass (weight) of materials that are required to support an economic system, whether for use in production and consumption activities or not, and whatever their origin is (domestic, rest of the world). In economy-wide material flow accounting TMR equals TMI plus indirect (upstream) flows associated to imports. Adding indirect flows converts imports into their 'primary resource extraction equivalent'.
Source: OECD. (based on Eurostat, 2001)

TMR is an overall indicator developed by the Wuppertal Institute to describe, in terms of total tonnage, not only the amount of natural resources contained in the commodities produced by the economy, but also the indirect flows which are involved in such production. These material flows which remain outside of the economy include wood materials which are not used in logging (branches, needles, leaves and roots), earth and stone which is excavated in mining and quarrying along with usable ore and minerals, earthworks necessary in the construction of infrastructure systems (roads and communities) and erosion resulting from human activities (including intensive agriculture).
Source: Wuppertal Institute

Unused extraction, see Unused (material) flows

Unused (material) flows or Unused extraction

In material flow accounting, unused (material) flows refer to flows of materials that originate from the environment, but do not physically enter the economic system as input for further processing or consumption

and return to the environment as residuals immediately after removal/displacement from their natural site. They are not incorporated in products at any stage and are usually without economic value.

Unused (material) flows mainly consist of unused extraction, i.e. materials that (i) are extracted, moved or disturbed by economic activities on purpose and by means of technology, (ii) are not fit or not intended for use in further processing, and (iii) remain unused in the environment. This is the case when material must be extracted from the natural environment, along with the desired material, to obtain the desired material, or when material is moved or disturbed to obtain the natural resource, or to create and maintain an infrastructure,

Examples of unused extraction are soil and rock excavated during construction and not used elsewhere, dredged sediments from harbours, overburden from mining and quarrying and unused biomass from harvest.
Source: OECD. (based on Eurostat, 2001)

The WRI distinguished the following categories of unused (material) flows:

- "ancillary material flows", i.e. material that must be extracted from the natural environment, along with the desired material, to obtain the desired material. Examples are the portion of an ore that is processed and discarded to concentrate the ore; the portion of biomass that is removed from the land along with the logs or the grain, but is later separated from the desired material before further processing.
- "excavated or disturbed material flows", i.e. material that is moved or disturbed on purpose to obtain the natural resource, or to create and maintain an infrastructure, but that returns to nature immediately after removal from their natural site. Examples are overburden from mining and quarrying, soil and rock excavated during construction and not used elsewhere, dredged sediments from harbours.

Source: WRI

Used (material) flows or Used extraction

In material flow accounting, "used (material) flows" refer to flows of materials that originate from the environment and that physically enter the economic system for further processing or direct consumption (they are "used" by the economy). They are converted into or incorporated in products in one way or the other, and are usually of economic value. Used material flows are also called "used extraction".
Source: OECD.

Value chain analysis (VCA)

Value chain analysis (VCA) is a systematic approach to examining the activities that take place in a business and relating them to an analysis of the competitive advantages of the business. VCA has also become an increasingly useful approach to gain a comprehensive view of the various inter-locking stages involved from taking a good or service from the raw material to production and then to the consumer.
Source: ILO, Value chain analysis for policy makers and practitioners, Geneva, 2005.

Waste (solid)

The term "waste" usually stays for "solid waste". It refers to materials that are not prime products (i.e. products produced for the market) for which the generator has no further use for own purpose of production, transformation or consumption, and which he discards, or intends or is required to discard. Wastes may be generated during the extraction of raw materials during the processing of raw materials to intermediate and final products, during the consumption of final products, and during any other human activity. Are excluded:
-- Residuals directly recycled or materials directly reused at the place of generation (i.e. establishment);
-- Waste materials that are directly discharged into ambient water or air.
Source: OECD

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