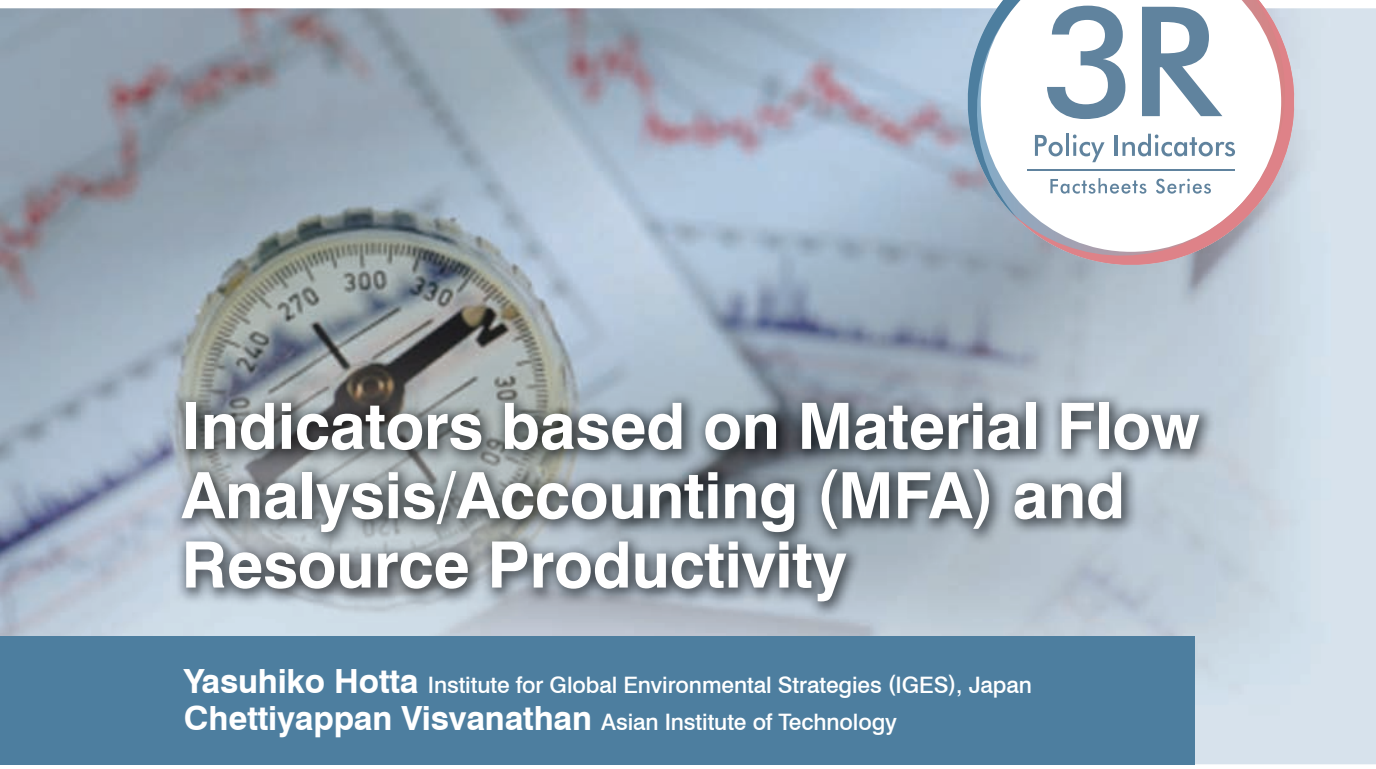
Ministry of the Environment

3R Policy Indicators Factsheets Series



Indicators based on Material Flow Analysis/Accounting (MFA) and Resource Productivity

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01 Outline of indicators

The global consumption of natural resources is soaring, especially in rapidly industrialising economies. This increasing demand is depleting the natural resource stocks and is also a major driver for other environmental problems, including climate change and the loss of biodiversity. Efficient resource use has become an issue for policy makers in their efforts to realise sustainable resource management.

Keeping an account of the resource inputs, extraction and consumption, as well as analysing the outputs (as waste) is a fundamental need when planning resource efficiency and conservation. Material Flow Analysis/Accounting (MFA) is an analytical method of quantifying flows and stocks of materials or substances in a well-defined system. MFA can be applied at several levels, such as product, regional and national economy level. The accounting may be directed at selected substances and materials, or at total material input, output and throughput (Figure 1). Nevertheless, all of these analyses use the accounting of material inputs and outputs of processes in a quantitative manner, and many of them apply a system or chain perspective.

Factsheets Series on 3R Policy Indicators
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Subject to further revision

Type of analysis	I		
	a	b	c
Objects of primary interest	Specific environmental problems related to certain impacts per unit flow of:		
	substances e.g. Cd, Cl, Pb, Zn, Hg, N, P, C, CO_2, CFC	**materials** e.g. wooden products, energy carriers, excavation, biomass, plastics	**products** e.g. diapers, batteries, cars
	within certain firms, sectors, regions		
	II		
	a	b	c
	Problems of environmental concern related to the throughput of:		
	firms e.g. single plants, medium and large companies	**sectors** e.g. production sectors, chemical industry, construction	**regions** e .g. total or main throughput, mass flow balance, total material requirement
	associated with substances, materials, products		

Figure 1: Types of material flow analyses
Source: Bringezu and Moriguchi, 2002

02 Macro-level MFA (Economy-wide MFA)

Material flow analysis/accounting (MFA) is the study of material flows on a national or regional scale. It is therefore sometimes also referred to as regional, national or economy-wide material flow analysis. MFA is one of the analytical tools that **make it possible to monitor countries' resource consumption trends and efficiency in resource use at the macro level. It uses already available production, consumption and trade data in combination with environmental statistics (OECD 2008).** In principle, MFA can show not only types and amounts of natural resources flowing into the economy, but also reveals what happens to materials as they move inside and out of the economy, and how this relates to resource productivity as well as environmental burden (OECD 2008). It also makes it possible to assess the environmental burden through economic activities of a nation, and determine how material-intensive an economy is.

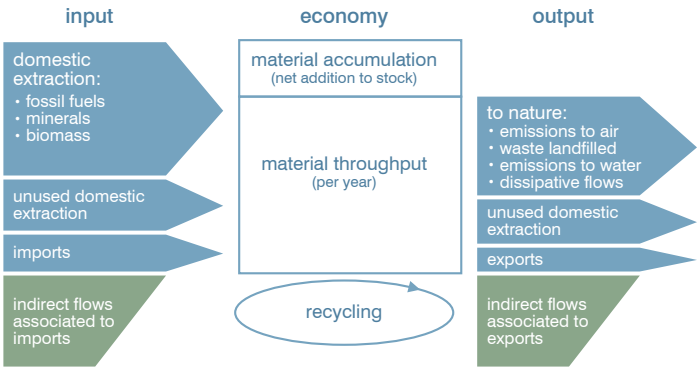

Figure 2: General scheme for economy-wide MFA
Source: Eurostat 2001

Among the existing guidelines, the OECD has developed a comprehensive set of materials called "Measuring Material Flows and Resource Productivity" for conducting Material Flow Analysis for policy makers. These materials cover 1) General OECD guide, 2) Accounting Framework, 3) Some examples of country activities, and 4) Specific module-based practical guidelines for assisting policy makers in implementing national material flow accounts. For those readers who want to know more about MFA, this factsheet recommends the OECD guide **"Measuring Material Flows and Resource Productivity"** as a major information source. It is available at: http://www.oecd.org/env/indicators-modelling-outlooks/resourceefficiency.htm

03 Type of indicator

Quantitative indicator, Pressure indicator, Response indicator

04 Policy goals to be monitored by these indicators

Indicators that are based on the MFA help to identify the inefficient use of natural resources, energy and materials in process chains or the economy at a macro-level (OECD 2008). Thus, these indicators are some of the most significant tools for monitoring policy and international efforts for improving efficient use of resources as well as sustainable resource management. They can provide an integrated view of resource flows through the economy, and look at capture flows (hidden flows or the so-called "ecological rucksack", such as mining overburden, harvest losses, pollution and waste generated upstream in the production process etc.) that do not enter the economy but are relevant from an environmental point of view. In addition the indicators can reveal how material flows shift within countries and between countries beyond their national borders.

05 Indicators

Statistics related to material flows are usually combined in different indicators. Some examples of material flow indicators are presented below(the following definitions are based on the OECD 2008). These indicators are usually represented by weight; i.e. tonnes.

The following indicators are commonly used in material flow accounting to measure the resource efficiency of a country or region:

Input Indicators

Domestic extraction used (DEU): DEU measures the flows of materials that originate from the environment and physically enter the economic system for further processing or direct consumption.

Direct Material Input (DMI): DMI comprises all materials which have economic values and are directly used in production and consumption activities.
DMI = DEU + import.

Total Material Requirement (TMR): TMR includes the indirect (used and unused) material flows associated with the imports of an economy but that take place in other countries. Thus, TMR is the most comprehensive material input indicator as it is comprises all input flows. It can measure the total material base of an economy and the possible indirect impact of material use.

Consumption Indicators

Domestic Material Consumption (DMC): DMC represents the total quantity of materials used within an economy.
DMC = DMI – Exports

Total Material Consumption (TMC): TMC measures the total material use associated with domestic production and consumption activities.
TMC = TMR- exports and its indirect flows.

Balance Indicators

Net Addition to Stock (NAS): NAS describes the annual accumulation of materials within the economic system (neither released into the domestic environment nor exported, but contributing to a physical increase of the economic processing system itself) and thus could also be termed "physical growth of the economy". NAS shows how materials in buildings, infrastructures and durable goods, such as cars and industrial machinery are expanding in an economy.

Physical Trade Balance (PTB): PTB expresses whether resource imports from overseas exceed the resource exports of a country, or global region, and to what extent domestic material consumption is based on domestic resource extraction or on imports from abroad. PTB reflects the physical trade surplus or deficit of an economy.
PTB = Imports-Exports

Output Indicators

Domestic processed output (DPO): DPO is defined by the OECD as the total mass of materials which have been used in the national economy, before flowing into the environment. These flows occur at the processing, manufacturing, use, and final disposal stages of the economic production-consumption chain. This equals the flow "outputs to nature" and comprises all outflows of used materials from domestic or foreign origin. DPO includes emissions to air and water, wastes deposited in landfills and dissipative flows. However, recycled materials are not included in the DPO indicator.

Total material output (TMO): Sum of domestic processed output (DPO) and export as well as unused domestic extraction. Thus it is comprised of all three categories of output flows either release to the environment, export and unused extraction.

Hidden Flows are materials that are extracted or moved, but do not enter the economy. According to the OECD hidden flows can be described as the "displacement of environmental assets without absorption into the economic sphere". One example of a hidden flow is unused materials from mining operations.

Resource Efficiency Indicators

GDP/DMI: GDP per DMI can indicate the direct materials productivity. Japan uses this indicator to measure its resource productivity to monitor the progress of its Fundamental Plan for Sound Material Cycle Society. Germany uses raw material productivity: GDP per DMI-biomass for its National Sustainable Development Strategy.

GDP/DMC: GDP per DMC can indicate the materials productivity of a domestic economy. The EU employs this indicator as a part of its Sustainable Development Indicator.

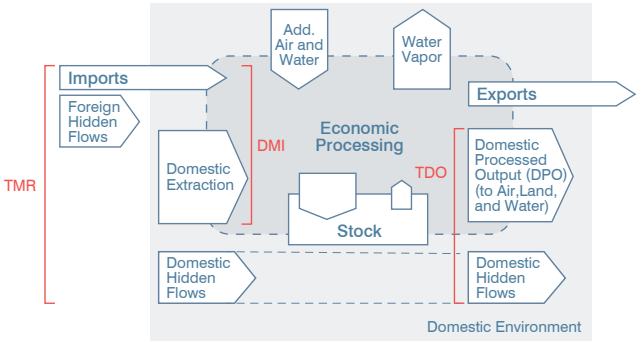

Figure 3: An economy-wide MFA scheme
Source: Matthews et al. (2000)

Indicator Classes	Indicators or aggregates		Accounting rules
	Acronym	Full name	
Input			
	DMI	Direct Material Input	DMI=Domestic materials+Imports
	TMR	Total Material Requirement	TMR=DMI+HF(unused extraction and IF)
Output			
	DPO	Domestic Processed Output	DPO=emissions+waste+dissipative flows
	DMO	Direct Material Output	DMO=DPO+Exports
Consumption			
	DMC	Domestic Material Consumption	DMC=DMI-Exports
	TMC	Total Material Consumption	TMC=TMR-Exports-hidden or indirect material flows of exports
Balance			
	NAS	Net Additions to Stock	NAS=DMI-DPO-Exports
	PTB	Physical Trade Balance	PTB=Imports-Exports
Efficiency			
	GDP/Input or Output indicator	Material productivity of GDP	GDP divided by indicators values (€ per mt)
	Unused/Used	Resource-efficiency of materials extraction	Ratio of unused (hidden or indirect) to used (DMI) materials

Table 1: Aggregates of MFA Indicators
Source: (Eurostat 2001)

Note: HF: hidden flows; IF indirect flows

06 Material flow accounting for domestic solid waste issues

MFA is a suitable method to model waste management systems as it supports decision-making in waste management from the viewpoint of material recycling. MFA in the waste sector can form a baseline scenario to assess future development. In addition it supports material flow management by identifying the priority areas to consider for distributing waste flows to various constructions taking into consideration technical, economic and ecological framework conditions.

The following published documents have made use of MFA in Waste Management Planning and Recycling:

- Bogucka, R., Kosinska, I., and Bruner, P.H. (2008). *Setting priorities in plastic waste management – lessons learned from material flow analysis in Austria and Poland.* Popular pustics & packaging, Nov 2008.
- Hong, S., et.al., (2011). *Material flow analysis of paper in Korea. Part I. Data calculation model from the flow relationships between paper products.* Resources, Conservation and Recycling, 55 (2011) 1206– 1213
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- Umberto Arenaa,b,*, Fabrizio Di Gregorioa. A waste management planning based on substance flow analysis.
- Vujić, G. V., *et.al*.: Assessment of Plastic Flows and Stocks in Serbia Using Material Flow. Thermal Science: Year 2010, Vol. 14, Suppl., pp. S89-S95

07 Methodologies to estimate material flows

It is advisable to carefully consider the purpose and existing capacity to conduct this analysis as it is a very data-intensive exercise. The OECD (2008) recommends that countries consider 1) the purposes and uses for which the accounts are established, 2) institutional arrangements and partnerships (establishing focal points and a scientific basis) for continuous efforts, 3) cost and benefit, and 4) already available statistical base. It is advisable to take a stepwise approach. For example the OECD 2008 shows the following steps:

Module 1 for tracing input flows into the economic system and disaggregation by materials and material categories.

Module 2 for expanding Module 1 by adding information on output flows to establish simple material flow balances.

The simple resource efficiency of an economy can be measured by developing Module 1 and 2.

Module 3 to disaggregate material use by different economic sectors.

Module 4 to address hidden flows associated with imports (and to exports).

Module 5 to address the side effects of the extraction of materials or environmental impacts from material consumption and extraction.

Module 6 to assess the changes in material stocks in a national economy.

These are still on-going efforts by researchers and experts, especially Modules 4-6 are still under development.

08 Merits of implementation

Unless material flows are monitored on a regular basis, it is difficult to design policies for improved resource efficiency and impossible to assess whether such policies are effective.

09 Material flow accounting and its application

The following section is based on the OECD Working Group on Environmental Information and Outlooks (WGEIO) special session on material flow accounting.

I. The experience of Japan

The MFA was studied mainly in response to the domestic issue of increasing solid waste. A flow chart describing Japan's macroscopic material flow balance was published in the annual 'Quality of the Environment' report. In Japan, the MFA has already been used as a part of reporting on the state of the environment, and for the development of environmental indicators. Since 2003, Japan has introduced MFA based indicators to monitor the progress in its national efforts for establishing a Sound Material-Cycle Society.

Every year, the government monitor and check the trend and data of these indicators. And every five year, the Fundamental Plan including the targets based on these indicators is going to be revised. These targets are resource productivity (GDP/DMI), cyclical use rate (cyclical use amount/(cyclical use amount + DMI)], and final treatment of waste. In 2003 Japan introduced MFA-based indicators and policy targets for 2010 to monitor the progress of 3R implementation at the macro-level. Since it was likely to achieve these targets for 2010, new targets were set for 2015 in the second Fundamental Plan in 2008. Again in 2013 new targets were set for the third Fundamental Plan. Japan is also monitoring its TMR.

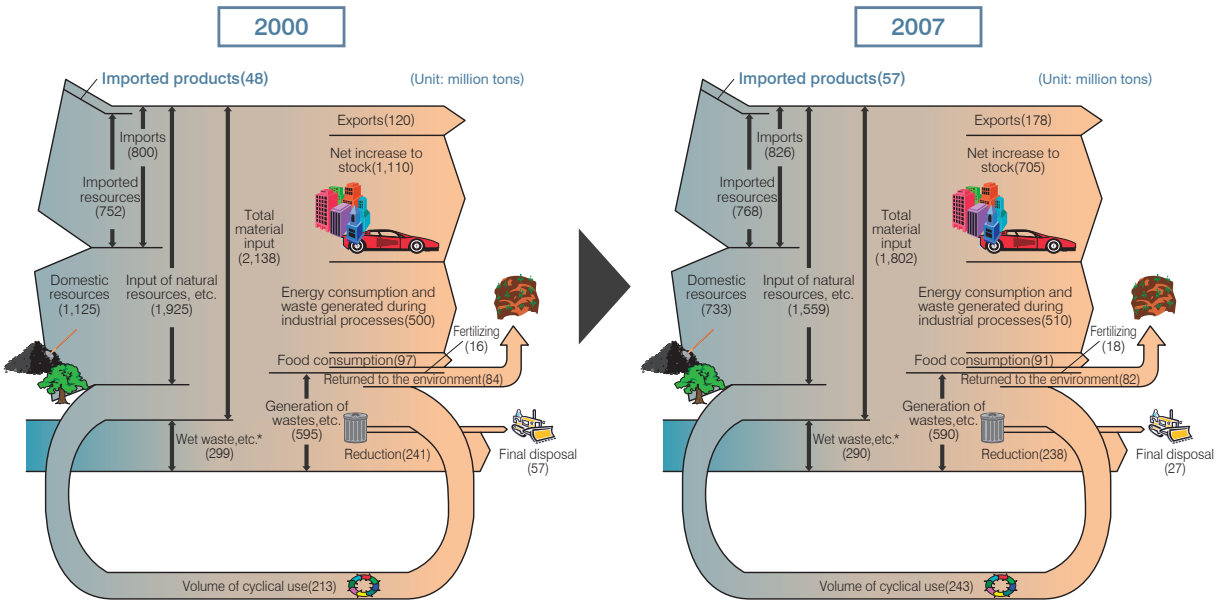

Figure 4: Material Flow of Japan (2000 and 2007)
Source: Ministry of the Environment of Japan (2011),

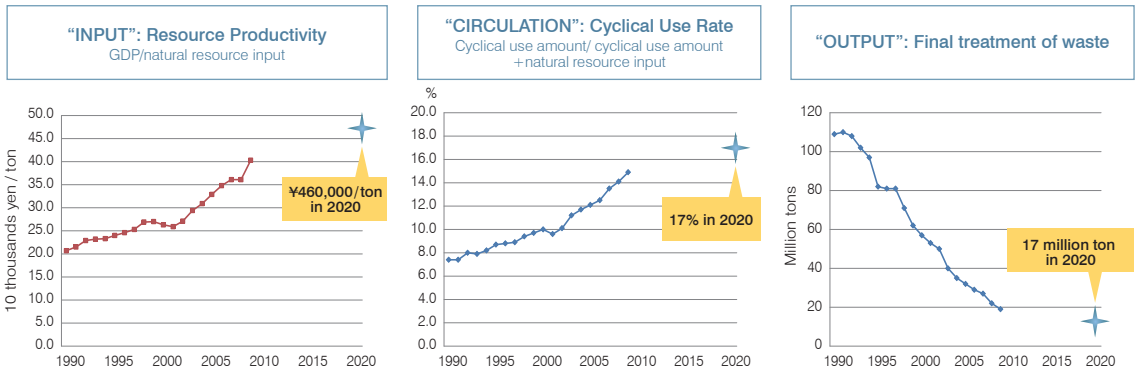

Figure 5: MFA-based indicators in the Fundamental Plan of Sound Material Cycle Society of Japan
Source: The 3rd Fundamental Plan for Establishing Sound Material Cycle Society (2013)

II. The experience of Canada (based on information of Statistics Canada)

The Material and Energy Flow Accounts (MEFA) record in substantial detail the annual flows of materials and energy—in the form of resources and wastes—between the Canadian economy and the environment. The accounts record the quantities of natural resources produced (that is, harvested or extracted) by industries, households and governments, and show how these resources are consumed by these same agents. Likewise for wastes, the accounts show the quantities produced by each agent and how these wastes are "consumed," either as recycled materials or as flows into waste disposal sites or to the environment. The MEFA share their classifications of industries, households and governments with Statistics Canada's Input-Output Accounts.

III. The experience of Sweden

Statistics Sweden developed material flow statistics for Sweden, with the objective of aggregating the description of the total material throughput for the society, as well as working towards eco-efficiency by improving resource productivity. The results contribute to provide a link between society's use of materials and natural resource accounting.

IV. The experience of the EU

Germany also monitors raw material productivity (GDP/DMI-biomass). The EU is also publishing a Resource Productivity Indicator for EU-27 countries (Eurostat 2012).

10 Application to developing countries in Asia and the Pacific

Aoki-Suzuki et al. (2012) suggests that the application of EW-MFA is still very limited in developing countries. It nevertheless has become a fast-growing field of research with increasing policy relevance (Bringezu and Moriguchi, 2001).

The Asia-Pacific Material Flows online databases of CSIRO and UNEP provide estimates of national total domestic extraction, DMC, and PTB For most countries in the Asia-Pacific region. These databases include indicators related to resource efficiency (GDP/DMC etc.) as well as four major and eleven detailed different categories of material-related data for extraction, DMC, and PTB between 1970-2008.
http://www.cse.csiro.au/forms/form-mf-start.aspx

In the developing countries surveyed by Aoki-Suzuki et al. (2012) a large number of organisations, including governmental bodies and academia, are collecting statistics relevant to MFA, but data collection is fragmented. There is a lack of coordination, and it is difficult to get an overview of existing data. Furthermore, there is still relatively low awareness among policy makers of the potential benefits of MFA.

Thus Aoki-Suzuki et.al. (2012) recommend increased international collaborative efforts that focus on the following: (a) establishment of national focal points for coordination of MFA data collection and compilation in each country; (b) development of case studies illustrating how MFA has provided policy makers with an improved basis for policy design and evaluation; (c) training and capacity development to harmonise data definitions and documentation formats, building on the work already done by the OECD and the EU; and (d) international collaborative research projects to further develop the capacity of academia and research institutes to analyse MFA data and effectively engage with policy makers.

Reference documents and existing guidelines

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