Economy–wide MFA (EMFA)
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The tool family of Material Flow Analysis (MFA)

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1 Introduction to MFA

The term Material Flow Analysis comprises a set of related descriptive and analytical tools which have as a common basis the paradigm of industrial metabolism (Ayres and Simonis 1994, Ayres and Ayres 2002). All MFA methodologies serve as tools to understand the functioning of the physical basis of societies, the interlinkages of processes and product chains, and the exchange of materials and energy with the environment (Moll et al. 2003). Common attribute is the principle of mass balancing.

According to Feminar and Moll (2005) who have developed their own characterisation of MFA tools according to kind and level of disaggregation there have been different attempts to classify MFA methodologies (e.g. Bringezu and Kleijn 1997, Bringezu and Morigushi 2002, Bringezu et al. 2003, Udo de Haes et al 2000, Daniels and Moore 2002, Fischer−Kowalski and Hüttler 1998). Bringezu and Moriguchi (2002) distinguish between two basic strategies according to the primary interest of the analyst (see Table 1). The first strategy may be characterized as detoxification of the industrial metabolism. This means to reduce the release of hazardous substances to the environment in order to provoke less pollution. Related tools are the substance flow analysis (SFA), the bulk material flows analysis or the life cycle assessment (LCA).

The second strategy could be described as dematerialization of the industrial metabolism. Dematerialization means to increase the resource efficiency by decoupling material use and economic growth, i.e. to produce more (or the same) by simultaneously using less primary material input.

Table 1: Types of material flow–related analysis (Bringezu and Moriguchi 2002 adopted from Bringezu and Kleijn 1997)

<table>
<thead>
<tr>
<th>Type of analysis</th>
<th>Specific environmental problems related to certain impacts per unit flow of:</th>
<th>within certain firms, sectors, regions</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>substances</td>
<td>e.g. Cd, Cl, Pb, Zn, Hg, N, P, C, CO₂, CFC</td>
</tr>
<tr>
<td>b</td>
<td>materials</td>
<td>e.g. wooden products, energy carriers, excravation, biomass, plastics</td>
</tr>
<tr>
<td>c</td>
<td>products</td>
<td>e.g. diapers, batteries, cars</td>
</tr>
</tbody>
</table>

<table>
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<th>III</th>
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<tbody>
<tr>
<td>a</td>
</tr>
<tr>
<td>b</td>
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<tr>
<td>c</td>
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<td></td>
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<td></td>
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</tbody>
</table>

The substance flow analysis (SFA) concentrates on the flow of one specific substance or a limited group of substances potentially harmful to the environment, e.g. heavy metals, through the industrial metabolism. In order to provide quantitative risk analysis the SFA reveals substance’s input pathways, stocks and outputs of the industrial system, regarding chemical, physical and biological transformations under specific temporal and
spatial conditions (van der Voet 2001).

Bulk material flows analysis focuses on base materials for industrial purpose, e.g. timber products and construction materials. The flow of per se rather harmless materials may be linked with other materials flows causing harmful environmental impacts (ecological rucksacks).

Life Cycle Assessment (LCA) is primarily used to describe the environmental impacts of certain products and services. By assessing the product’s lifecycle from ‘cradle to grave’ an increasingly complex chain of materials is to be considered. Thus, the LCA is more specific and broader than SFA or bulk material flow analysis. For more information see Lifecycle assessment.

1.1 Introduction to economy–wide MFA and derived indicators

Economy–wide MFA is used to analyse the societal metabolism in order to understand how it works. The results are the basis for evaluation and possible structural change (Bringezu et al. 2003). Economy–wide MFA provides an overview of annual material inputs and outputs of an economy including inputs from the national environment and outputs to the environment and the physical amounts of imports and exports (Eurostat 2001). The accounts are in physical units, usually tonnes per year. Economy–wide MFA is based on the mass balance concept and account systematically for all material input and output flows crossing the functional border between economy (technosphere, anthroposphere) and environment. MFA also considers material flows crossing the national (geographical) border, i.e. imports and exports and traces them back to the functional economy–environment border. Economy–wide MFA is supposed to form a physical complement to the monetary System of National Accounts. The mass differences between material inputs and outputs relate to the physical stock changes within the national economy. At the overview level, economy–wide MFA do not account for the internal material flows within the economy (e.g. between production units). Those are shown in more detail e.g. by Physical Input–Output Tables (PIOT).

2 Methodology of economy–wide MFA

Economy–wide MFA accounts for material exchange between national or regional economies and (a) the domestic environment (via resource extraction on the input side and waste deposition, and releases to air and water, dissipative uses and losses (on the output side), and (b) other economies (via trade) through measuring material flows in physical units (in particular metric tons).

In economy–wide MFA a distinction is made:

- a. between used and unused materials extraction (the latter is not further processed and has no economic value but nevertheless connected to environmental pressures), and
- b. between direct and indirect flows.

Direct flows in EWMF comprise the used part of domestic extraction and the total mass of imported (and exported) commodities via foreign trade. Indirect flows comprise, for example, the upstream resource requirements (used or unused) associated with imported commodities of an economy.

The so–called ‘hidden’ flows (Adriaanse et al. 1997) are either unused domestic extractions moved/removed in order to get access to the wanted raw materials (e.g. mining waste); these are called ‘domestic hidden flows’; or, they are associated with imports and relate to the cradle–to–border primary material requirements which had been necessary to produce the imported good; these are termed ‘foreign hidden flows’, which is in line with the concept of indirect (foreign) flows.

Figure 1: Main components of an economy–wide MFA (Eurostat 2001).
Inputs from the environment (material inputs, MI, used or unused) are defined as the extraction or movement of natural materials on purpose and by humans or human controlled means of technology.

According to the Eurostat methodological guide (Eurostat 2001), the following components are distinguished on the material input side of an economy-wide MFA:

1. **Used domestic extraction** i.e. raw material extractions from the domestic environment which are directly used in subsequent economic processing (e.g. fossil fuels, metals, industrial minerals, construction minerals, biomass etc.)

2. **Unused domestic extraction (domestic hidden flows)** i.e. those primary material inputs associated with the above mentioned used domestic extractions which are not directly used in economic processing (‘hidden’) and hence are not valued economically (overburden), from biomass harvest (discarded by−catch, wood harvesting losses etc.), and soil (and rock) excavation and dredged materials (materials extracted during construction and dredging activities)

3. **Imports** i.e. the materials of goods imported to the national economy

4. **Indirect flows associated with imports (foreign hidden flows)** i.e. the ‘hidden’ cradle−to−border primary resource extractions (used and unused) that have been required to produce the imported good (often referred to as ‘ecological rucksacks’)

Each item of the material input account is disaggregated by main materials categories (i.e. fossil fuels, metals, industrial minerals, construction minerals, and biomass).

On the material output side of an economy-wide MFA, the following components are distinguished:

1. **Processed outputs to nature** i.e. the results of production or consumption processes, classified into
   - Emissions and waste flows
   - Dissipative use of products and dissipative losses

2. **Exports** i.e. the materials of exported goods

3. **Unprocessed outputs (disposal of unused domestic extraction)** equals the unused domestic extraction (domestic hidden flows)

4. **Indirect flows associated with exports** i.e. the ‘hidden’ lifecycle−wide primary resource extraction that had been required to produce the exported good (often referred to as ‘ecological rucksacks’)

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Economy–wide MFA (EMFA)

Air and water are not included in the accounts, but they are used as balancing items to maintain equal input and output mass quantification with regard to the second law of thermodynamics (e.g. oxygen input of emissions to the air or water output of biomass consumption).

2.1 Main MFA indicators

Economy–wide MFA constitute the basis from which a variety of material flow based indicators can be derived (see Table 2). The Eurostat MFA methodological guide stresses that the choice of the most relevant indicators is still open and will depend on the experiences to be made with policy analyses and policy applications of resource use indicators. ‘At present, good candidates for core indicators would be the input indicators DMI and TMR as well as the consumption indicators DMC and, maybe, TMC (the latter being difficult to estimate because of the need to estimate the indirect flows associated to exports). NAS and PTB may be interesting supplementary indicators’ (Eurostat 2001). These indicators are briefly introduced in the following.

Table 2: Aggregated indicators derivable from economy–wide MFA (Eurostat 2001)

<table>
<thead>
<tr>
<th>Indicator classes</th>
<th>Indicators or aggregates</th>
<th>Accounting rules</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input</td>
<td>Indicators or aggregates</td>
<td>Acronym</td>
</tr>
<tr>
<td></td>
<td>DMI</td>
<td>Direct Material Input</td>
</tr>
<tr>
<td></td>
<td>TMR</td>
<td>Total Material Requirement</td>
</tr>
<tr>
<td>Output</td>
<td>DPO</td>
<td>Domestic Processed Output</td>
</tr>
<tr>
<td></td>
<td>DMO</td>
<td>Direct Material Output</td>
</tr>
<tr>
<td>Consumption</td>
<td>DMC</td>
<td>Domestic Material Consumption</td>
</tr>
<tr>
<td></td>
<td>TMC</td>
<td>Total Material Consumption</td>
</tr>
<tr>
<td>Balance</td>
<td>NAS</td>
<td>Net Additions to Stock</td>
</tr>
<tr>
<td></td>
<td>PTB</td>
<td>Physical Trade Balance</td>
</tr>
<tr>
<td>Efficiency</td>
<td>GDP/Input or Output indicator</td>
<td>Material productivity of GDP</td>
</tr>
<tr>
<td></td>
<td>Unused/Used</td>
<td>Resource–efficiency of materials extraction</td>
</tr>
</tbody>
</table>

Note: HF: hidden flows; IF: indirect flows

DMI (Direct Material Input) is defined as measuring the input of materials into the domestic economy which are of economic value and which are processed and used in production and consumption activities. DMI comprises the following components:

+ (a) domestic extraction used (DE)

• Fossil fuels (coal, oil…)

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• Minerals (metal ores, construction minerals, industrial minerals…)

• Biomass (timber, cereals…)

+ (b) (physical) imports

= Direct Material Input (DMI)

For a more detailed analysis, minerals are further broken down into metals, industrial minerals and construction minerals.

**TMR** (*Total Material Requirement*) is defined as accounting for the domestic resource extraction and the resource extraction associated with the supply of the imports (all primary materials except water and air). TMR thus measures the physical basis of an economy in terms of primary materials. It comprises raw materials which are further processed and which have an economic value (= ‘used extraction’), as well as so-called ‘hidden flows’, both domestic unused extraction and foreign indirect flows.

First, hidden flows (HF) refer to materials which are extracted or otherwise moved by economic activities but which do not normally serve as input for domestic production or consumption (mining waste such as overburden, erosion in agriculture etc.). This ‘unused extraction’ relates, for instance, to the hidden flows of primary production (either domestically or in foreign countries). These flows that are not further processed and have no economic value (e.g. mining waste) nevertheless burden the environment, especially in the local and regional surroundings of the extraction site (landscape changes, hydrological impacts, sometimes eco-toxic effects).

Second, the hidden or indirect flows of imports comprise the ‘cradle-to-border’ primary resource requirements that are linked to the provision of the imports (comprising upstream unused and used extraction).

Therefore, the TMR account comprises hidden (indirect) flows in addition to DMI:

= Direct Material Input (DMI)

+ (c) unused domestic extraction

• From mining/quarrying

• From biomass harvest

• Soil excavation (and dredging)

• Erosion from agricultural land

+ (d) indirect flows associated to imports

= Total Material Requirement (TMR)

As for DMI, these main material categories can be further detailed in the course of more refined analysis.

**DMC** (*Domestic Material Consumption*) is defined as the total amount of materials directly used in a national economy (i.e. excluding indirect flows) and remain physically in the country (i.e. exports are subtracted).
DMC is defined in the same way as other key physical indicators such as gross inland energy consumption. DMC equals domestic used extraction plus imports minus exports (or more simply DMI minus exports):

+ domestic extraction used (DEU)  
+ (physical) imports  
= Direct Material Input (DMI)  
− (physical) exports  
= Domestic Material Consumption (DMC)

TMC (Total Material Consumption) is defined as the total (life-cycle-wide) material use associated with the domestic consumption activities, including indirect flows imported (see TMR) but less exports and associated indirect flows (whereas TMR is related to the production activities incl. trade). TMC equals TMR minus exports and their associated indirect flows:

+ domestic extraction used (DEU)  
+ (physical) imports  
= Direct Material Input (DMI)  
+ unused domestic extraction  
+ indirect flows associated to imports  
= Total Material Requirement (TMR)  
− (physical) exports  
− indirect flows associated to exports  
= Total Material Consumption (TMC)

NAS (Net Additions to Stock) measures the ‘physical growth of the economy’, i.e. the quantity (mass) of materials net added to the stock of buildings and other infrastructures, materials incorporated into new durable goods such as cars, industrial machinery, and household appliances. In principal, NAS equals the DMI minus exports minus DPO:

= Direct Material Input (DMI)  
− (physical) exports  
− Domestic Processed Outputs (DPO)  
= Net Additions to Stock (NAS)
PTB \textit{(Physical Trade Balance)} is defined as the physical trade surplus or deficit of an economy. PTB equals imports minus exports.

\[ + \text{(physical) imports} - \text{(physical) exports} = \text{Physical Trade Balance (PTB)} \]

Physical trade balances might also be set up for single materials categories (e.g. for fossil fuels) but also for indirect flows associated to imports and exports.

\section*{3 Process of economy–wide MFA}

The economy–wide MFA is an advanced methodology which is applied in the EU and abroad. The approach of the ‘economy–wide material flow accounts and derived indicators’ has been first laid down in a methodological guide (Eurostat 2001). The harmonized statistical data basis facilitates comparable analysis in different EU Member States. The methodological guide serves as reference also on the international level. The Ministerial Council of the OECD recommends to measure their material productivity by applying material flows analysis (OECD 2004). Basic methodologies and practical applications are currently (in the course of 2006) harmonized by Eurostat and OECD.

To carry out an economy–wide MFA the following steps have to be taken (Eurostat 2001; Bringezu and Moriguchi 2002; Brunner and Rechberger 2004).

\subsection*{First step: defining the system boundary}

The focus of economy–wide MFA and balances is on the economy’s metabolism, i.e. on the flows between a given economy and the environment. Therefore, the system boundary is defined:

1. by the extraction of primary (i.e. raw, crude or virgin) materials from the national environment and the discharge of materials to the national environment;
2. by the political (administrative) borders that determine material flows to and from the rest of the world (imports and exports). Natural flows into and out of a geographical territory are excluded.

\subsection*{Second step: identification of the relevant flows and stocks accounting}

The main categories of flows and stocks to be accounted for with an economy–wide MFA have three dimensions:

- the territorial dimension to indicate the origin and destination of flows;
- the product–chain or lifecycle dimension to indicate whether flows are directly measured or flows are calculations of upstream material requirement;
- the product dimension to indicate whether flows enter economic system or not.

The choice of materials being accounted and the degree of detail depends on the focus of the assessments and on data availability. For example, the used Domestic Extraction (DE) usually consists of the main categories fossil fuels, biomass, metals, construction minerals and industrial minerals.

\subsection*{Third step: determination, accounting and balancing of the relevant flows and stocks}

The identified material flow indicators can be determined in flow accounts, although some derived indicators (e.g. DMI, DMC, NAS) can be determined without these accounts. Flow accounts are further quantified in PIOT (Physical Input Output Tables) and describe the flows of material and energy between the economic
system and the natural environment. They also describe the physical man–made accumulation of materials in the economy, but not the stocks of natural capital.

Fourth step: Presentation, Modelling and evaluation of the results

In general the main results are presented in clearly arranged charts and tables. Figure 2 gives an example of how the results can be displayed. It shows as an example the economy–wide material balance of the EU, which represents an aggregated result of the economy–wide MFA. On the left hand the inputs to the economy in tons per capita are shown consisting of imports and their associated foreign hidden flows as well as the domestic used extraction and their associated domestic hidden flows. The Direct Material Input (DMI) enters the economic processing, where a part of it is accumulated (NAS). The output side consists of the Domestic Processed Outputs (DPO) with their hidden flows released to the domestic environment, and the exports leaving the domestic environment. Thus, an overview of the main input and output flows is given.

Figure 2: Estimated economy–wide material flows in the EU, on a per capita year basis and for the second half of the 1990ies (Moll et al. 2003).

The results of an economy–wide MFA modelling can be further processed. By linking resource use and impact potentials the exploration of environmental implications of resource use is possible (Moll et al. 2004, van der Voet 2004). Advanced dynamic modelling is feasible, too, e.g. by combining the results of economy–wide MFA with econometric models.

4 Review of economy–wide MFA

4.1 Evaluation results of economy–wide MFA

Economy–wide MFA is a tool applied in several countries, especially in Europe (Eurostat 2001). It provides data input for several tools, such as NAMEA, integrated scenarios and prospective modelling, especially
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scenario tools, multi criteria analysis, environmental appraisal tools, transition management, stakeholder analysis and modelling.

Economy–wide MFA is useful in some stages of the policy process, especially in the recognition of a problem, investigating its nature and exploring possible solutions.

Within the three pillars of sustainability economy–wide MFA addresses foremost the environmental topics particularly well, although not every single topic is covered. Apart from the determination of equitable shares of global resource consumption, economy–wide MFA is not suitable to cover social topics. Economic topics may be covered partially. Economy–wide MFA is well suited to reveal the physical side of international trade.

The data needs are high in case a full–fledged material balance including TMR and TMC is performed. The cost of an economy–wide MFA depends on its extent. The data availability varies broadly, depending on the particular case. The technical equipment needed to carry out the assessment is limited to usual PC equipment and software.

The complexity of the tool depends on the level of detail. There are harmonised methods and standardised steps of application available (Eurostat 2001 and ongoing joint activities by Eurostat and OECD). Although there is a clear structured data gathering procedure (input flows, output flows), the specific details may hold difficulties. The reliability strongly depends on data availability and quality. Uncertainties are not easy to be overcome, but their sources can in most critical cases be identified and named.

The experience with the tool can be considered as high. Several studies all over the world have been carried out, especially in European countries. Although there is no mandatory usage yet (although proposed by Eurostat), economy–wide MFA is recommended by OECD.

Depending on data availability, all countries or groups of countries (e.g. EU) can be investigated, and even regional economies like federal states or other administrative units. For retrospective analysis the analysis can cover decades; for prospective analysis decades can only be covered in combination with prospective modelling. Results are as well possible on a highly aggregated level as on disaggregated levels.

4.2 Roots of and practical experiences with economy–wide MFA

After initial attempts in the late 1960s (Ayres and Kneese 1969) the principles of statistical approaches towards material flow accounts and material balances have been formulated in the 1970s (see e.g. United Nations 1976). In Europe, material flow accounts are part of official statistics in several EU Member States and EFTA countries (see Eurostat 1997, 2001). A recent inventory of country activities related to the measurement and analysis of resource and material flows was undertaken by the OECD (2005). The idea of economy–wide aggregated material flow accounts and balances (as opposed to single–material or substance accounts) has been applied already in the 70s (see e.g. Gofman et al. 1974), and was re–vitalised in the early 90s and put into statistical practice in e.g. Austria (Steurer 1992, Fischer–Kowalski and Haberl 1993), Germany (Schütz and Bringezu 1993), Japan (Japanese Environmental Agency 1992) and the USA (Rogich et al 1992, Wernik et al. 1996).

The material flow balance approach was extended to consider transnational resource extractions induced by domestic demand and to indicate the total material use of an economy (Bringezu et al. 2003), including the so–called ecological rucksacks (Bringezu 1993; Bringezu and Schütz 1995). Schmidt–Bleek (1993) had coined the term ‘ecological rucksack’ for a product to indicate those primary requirements that do not enter the product itself. Bringezu (1993) related this idea to national material flow balances, accounting for the ecological rucksacks of imports and exports. This method provided the basis for the first international comparisons through the Resource Flows report (Adriaanse et al. 1997), which focused on the total material requirements of national economies, since then ecological rucksacks have also been termed ‘hidden flows’ (HF) (see also section 2.1). The second, widely acknowledged Weight of nations report (Matthews et al. 2000) focused on the output of the economy to the environment.
A variety of studies were undertaken in several countries, often supported by statistical and environmental offices, especially in Europe (Bringezu et al. 2003). For the EU and its Member States, Bringezu and Schütz (2001) provided material flow accounts and derived indicators. National material flow accounts – with focus on either material flow balances or on indicators or both – exists for Austria (Schandl 1998; Gerhold and Petrovic 2000; Matthews et al. 2000), China (Chen and Qiao 2000), Czech Republic (Scasny and Kovada 2002), Denmark (Pedersen 2002), Germany (Bringezu and Schütz 1995; Bringezu 2002b; Destatis 2001), Finland (Muukkonen 2000, Statistics Finland 1999; Mäenpää et al. 2000), Italy (De Marco et al. 2000; Fermia 2000; Fermia, ed. 2003, Fermia, ed. 2004), Japan (Moriguchi 2002), the Netherlands (Matthews et al. 2000), Poland (Schütz et al. 2002), Sweden (Palm and Jonsson 2003), United Kingdom (Vaze and Barron 1998; Bringezu and Schütz 2002; Schandl and Schulz 2000), and the United States (Adriaanse et al. 1997; Matthews et al. 2000; Rogich and Matos 2002). Preliminary accounts have been made for Egypt (el Mahdi 1999) and Amazonia (Lukesch et. al. 2002), and work is ongoing for Philippines, Laos, Thailand, and Vietnam.

**4.3 Combinations of economy-wide MFA with other tools**

MFA data can be used by other tools, which require quantitative units and indicators. This would link MFA to a number of impact assessment tools and application frameworks, especially scenario tools, multi criteria analysis, environmental appraisal tools, transition management, stakeholder analysis and modelling.

There is a direct connection to monetary assessment tools. Economy-wide MFA has been developed as a biophysical complement to economic accounts and hence is widely compatible with the accounting rules and conventions as laid down in the System of National Accounts (Bringezu 2003), see also section 6. Combining both types of information – as proposed by the UN System of Integrated Economic and Environmental Accounts (SEEA) (United Nations et al. 2003) – supports integrated macroeconomic and environmental analyses.

**4.4 Strengths and limitations of economy-wide MFA**

Economy-wide MFA and derived indicators have certain strengths and certain limitations. A systematic overview is given in Table 3.

<table>
<thead>
<tr>
<th>STRENGTHS</th>
<th>LIMITATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>MFA provides an overview of the metabolism of the economy, and retrospective analysis of the dynamics of volume and structure.</td>
<td>Status quo and current trends do not indicate a possibly sustainable future situation; for that purpose integrated scenarios and prospective modelling is required.</td>
</tr>
<tr>
<td>Economy-wide MFA provides the link between economic activities of a national economy and environmental impacts through pressure indicators, either on the output side (e.g. emissions) or on the input side (e.g. TMR).</td>
<td>The indicators are pressure indicators; they do not tell anything about specific impacts in terms of changes of the state of environment (neither output nor input related pressures do so).</td>
</tr>
<tr>
<td>Input based indicators quantify also the amount of subsequent output</td>
<td>Output indicators are not as easy and accurate to provide as input indicators</td>
</tr>
<tr>
<td>Indicators such as TMR account for the overall requirements of primary materials (analogous to primary energy consumption, but considering energetic and non–energetic materials as well as ‘embodied’)</td>
<td>In order to define input one has to determine (1) when a resource use is ‘primary’ (where does the ‘cradle’ stand?);</td>
</tr>
</tbody>
</table>
A complete material balance for an economy is statistically difficult to achieve since not all material input and output flows are observed in a systematic way. Some material flow categories must be estimated and available

<table>
<thead>
<tr>
<th>Economy–wide MFA (EMFA)</th>
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<tbody>
<tr>
<td>requirements).</td>
<td>(2) which resources are to be accounted for;</td>
</tr>
<tr>
<td></td>
<td>The results are dependent on accounting conventions, which may define the system boundary and the categories to be considered in different ways, depending on the objectives of interest.</td>
</tr>
<tr>
<td></td>
<td>These accounting conventions have been laid down by Eurostat (2001) and are currently reviewed by Eurostat and OECD for international harmonization.</td>
</tr>
<tr>
<td>Bulk material flow indicators such as TMR may be interpreted as indicators of generic environmental pressure which give rise to a bundle of consequences or impacts irrespective of the chemical composition; e.g. indicating the total amount of wastes and emissions to be expected as a consequence of resource input, and/or indicating a risk of unclassified or non– quantifiable impacts at the macro level (through landscape changes, loss of fertile soil etc.).</td>
<td>Bulk material flow indicators may not be used to indicate substance specific pressures (e.g. GWP); for this a complementary approach may be chosen by integrating material input indicators with indicators e.g. for greenhouse gas emissions.</td>
</tr>
<tr>
<td>Bulk material flow indicators may be designed to indicate the flows induced by the production (DMI, TMR) or consumption (DMC, TMC) side of the economy, as well as the resulting efficiencies (relations to GDP).</td>
<td>Unused extraction may have different impacts than further processed materials with regard to the subsequent outputs; therefore, the information on overall inputs should be complemented by the information on critical outputs.</td>
</tr>
<tr>
<td>Used and unused inputs can be accounted for; with regard to the impacts of resource extraction or harvest there is no general difference with regard to the subsequent routes of processing, or whether some of the materials will be assigned an economic value later.</td>
<td>Data availability and accuracy of hidden flows of imports and exports is lower than for domestic material flows. Hence, efforts should be undertaken on the international level to improve the database for unused and indirect flows.</td>
</tr>
<tr>
<td>Domestic and foreign material flows associated with domestic activities can be accounted for in order to detect shifts of environmental burden and of dependence on foreign resources.</td>
<td>MFA allows distinguishing between renewable and non–renewable inputs.</td>
</tr>
<tr>
<td>Economy–wide MFA reveals information on the physical dimension of foreign trade.</td>
<td>Concerning the renewables based on biomass there is a need to further qualify and quantify unsustainable and sustainable cultivation.</td>
</tr>
<tr>
<td>MFA allows quantifying the physical growth of the technosphere as an indicator of future waste volumes and of the distance from flow equilibrium (which is one precondition of a sustainable situation).</td>
<td>Assessing the implications of the expansion of the technosphere requires consideration of land use; an integrated resource management will have to consider material, energy and land resources.</td>
</tr>
</tbody>
</table>
data complemented by additional estimates (Eurostat 2001). The level of detail depends on the accounting categories, that is, the classification and aggregation of inputs and outputs.

An economy–wide MFA integrates quantitative information scattered in different accounts into a coherent balance account and thus also allows consistency checks in the underlying statistics (Eurostat 2001).

### 4.5 Further work of economy–wide MFA

MFA can be used as a basis to analyse the physical turnover of an economic system (from the micro to the macro level). On this basis it is possible to determine socially acceptable targets for resource use especially with the aim of decoupling environmental pressures from economic development.

The objective of decoupling environmental pressure from economic growth has been formulated by the European Council and the European Commission. It is also followed by several EU Member States (see Table 4). Outside Europe, Japan decided to minimize its resource productivity by 40% in 2010.

**Table 4: National objectives concerning decoupling in Europe.**

<table>
<thead>
<tr>
<th>Country</th>
<th>Target</th>
<th>Document</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>Factor 4</td>
<td>Austrian Strategy for Sustainable Development</td>
<td>Endorsed by Council of Ministers on 30 April 2002</td>
</tr>
<tr>
<td>Denmark</td>
<td>Limit resource consumption to 25% of current consumption</td>
<td>Denmark’s national strategy for sustainable development: A shared future – balanced development, the Danish government</td>
<td>August 2002</td>
</tr>
<tr>
<td>Germany</td>
<td>Doubling energy and raw materials productivity by 2020. In the long term factor 4</td>
<td>German Strategy for Sustainable Development</td>
<td>Passed by the Federal cabinet on 17 April 2002</td>
</tr>
<tr>
<td>Ireland</td>
<td>Progressive decoupling</td>
<td>Ireland’s Strategy for Sustainable Development: Department of the Environment and local government</td>
<td></td>
</tr>
</tbody>
</table>

The use of MFA data to determine overall environmental pressure is not only supported by EU–Member States activities, but also with the recommendation of the OECD Council on Material Flows and resource productivity endorsed by environment ministers on 20 April 2004 and adopted by the OECD Council on 21 April 2004 (OECD 2004).
Economy-wide MFA (EMFA)

With the further diffusion of MFA in OECD countries it will be possible to measure and compare to which extent decoupling takes place in industrial societies. The monitoring results can be a basis for planning targeted policy interventions. For this purpose research on innovation and governance to increase resource productivity should be intensified.

By decoupling resource use from economic growth a considerable reduction of environmental pressure can be expected. To which extent this might impact on the economic and ecological systems is subject of further research. This implies on the one hand better integration with econometric modelling and on the other hand improved coupling with life-cycle analysis and other physical assessment tools.

4.6 References


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