MATERIAL FLOW ANALYSIS (MFA) FOR RESOURCE POLICY DECISION SUPPORT

Position Paper of the Interest Group on the Sustainable Use of Natural Resources on the needs for further development of MFA-based indicators

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EXECUTIVE SUMMARY

On the long-term view all non-renewable resources are limited. A sustainable resource policy should establish an economy which uses natural resources efficiently and develops alternatives to the consumption of scarce resources or materials which cause high environmental impacts during extraction, use and deposition.

In order to be able to concentrate the resource policy measures on those materials and sectors of the economy with the narrowest supply bottle necks, with the highest optimization potentials and the highest environmental impacts in the short term and in the long term it is necessary to develop a thorough understanding of material flows on different levels.

Material flow analysis (MFA) is an established approach which allows getting this understanding. MFA can

- provide early warnings of problems lying ahead
- identify potentials for improvements
- show if the economy is on the right path with respect to resource productivity
- provide a basis for determining the environmental impact of resource use.

The objective of this position paper is to give to decision makers an understanding of

- what MFA is
- what the potentials of MFA for environmental and economic policy making are
- where MFA stands in its development and
- which additional steps are needed to achieve an optimum basis for future decision making.

The position paper introduces the approaches to and the methods of

- Economy wide MFA and their indicators
- MFA based on Input/Output tables
- MFA taking into account indirect (hidden) flows
- Substance Flow Analysis

by giving examples which are relevant to current environmental and resource policy. The paper also summarises the ground work provided by Eurostat and OECD, shows relevant activities in selected EU Member-States and introduces some resource use analysis approaches/indicators which are complementary to MFA.

As a first step to broaden the application of MFA, the Interest Group Resources of the Environmental Protection Agencies Network recommends:

- to develop and introduce standards for calculating the indirect flows and derived indicators such as TMR (total material requirement) and DMC_{RME} (domestic material consumption expressed in raw material equivalents) or an equivalent indicator – as a proxy for potential environmental pressures associated with the resource extractions
- to determine on a regular basis the TMR and DMC_{RME} or an equivalent indicator for each EEA member state ideally based on statistically reported data
- to use the TMR and DMC_{RME} or an equivalent indicator as basis to inform resource policy.

The Interest Group Resources of the Environmental Protection Agencies Network also recommends that the Environmental Protection Agencies:

- support the establishment of regular material flow accounting in their respective countries taking into account indirect flows;
- apply MFA indicators in their analyses.

1 INTRODUCTION AND OBJECTIVES

In the Thematic Strategy on the Sustainable Use of Natural Resources following sentence can be found: "An analysis of materials and waste streams in the EU, including imports and exports, showed that, in the last 20 years, overall consumption per inhabitant has remained virtually unchanged in the EU at around 16 tonnes per year, and yet the economy has grown by 50 % over that period" (EUROPEAN COMMISSION 2005). These figures are the results of a material flow analysis (MFA). It shows both, the importance of MFA for resource policy and the possibility of drawing wrong conclusions when neglecting system boundary effects.

The importance is shown as this sentence is the basis for the decision in the Thematic Strategy not to focus on resource conservation but rather on the environmental impact of resource use. A system boundary effect is the fact that domestic extraction and processing (including tailings and waste produced during the early stages of the life cycle) to some extent has been replaced by imports of processed commodities and goods (excluding the waste produced during the early stages of the life cycle).

MFA is defined as "systematic accounting of the flows and stocks of materials within a system defined in space and time. It connects the sources, the pathways, and the intermediate and final sinks of a material. Because of the law of conservation of matter, the results of an MFA can be controlled by a simple material balance comparing all inputs, stocks, and outputs of a process" (BRUNNER & RECHBERGER 2004).

Though MFA is also in use e.g. for optimising cleaner and leaner production on the plant level (OENORM S 2096-1,2 2005) this paper concentrates on the application of MFA for supporting national and international resource policy development.

With respect to the analysis of efficient and environmentally friendly resource use MFA has been applied in Europe in the following way:

- Time series of imports, exports, and domestic extraction of different substances, materials and goods show how the resource basis of a country develops over the years.
- Time series of domestic material consumption per capita show how the material needs of the domestic production and private consumers change over time.
- Time series of GDP over direct material input show how the resource productivity of an economy develops
- National MFA based on sectoral disaggregation shows the material flows between the different sectors, the build-up or depletion of anthropogenic stocks, the recycling or final storage of materials, domestic extraction imports and exports as well as emissions into the environmental media. This shows how the system works and allows identifying hot spots as focal points for further action.

MFA provides environmental pressure indictors but does not address environmental impacts. For example 1 ton of carbon as cellulose has a different environmental impact than 1 ton of carbon as dioxine. Nevertheless, if it can be assumed that the specific environmental impact per ton of material stays constant over time, an increasing material flow is an indicator of increasing environmental pressure.

One advantage of MFA is that it can provide a small number of indicators which contain the information of a whole national economy without weighing or applying normative valuation. For MFA there is a standardized method at hand, described in compilation guidance manuals. However, compilation and estimation methods are still diverging and when analysing and comparing MFA results underlying compilation and estimation methods have to be considered and evaluated. This is especially true when calculating the upstream material requirements of imports and exports of a country.

With respect to the global resource requirements of societies or economies, indicators that consider the upstream material requirements such as the TMR are needed. These indicators also take into account the indirect material flows in other countries connected to material imports. As the raw material basis of the European countries shifts more and more towards other continents the consideration of indirect material flows in a reliable and standardised way gains increasing importance for European resource policy. These indicators complement the well established indicators such as domestic material consumption (DMC) and direct material input (DMI).

It is the objective of this paper to

- show the importance of MFA and MFA indicators for supporting sustainable development policy making in general and for resource policy making in particular
- show the importance of MFA as basis for achieving the resource policy objective as the one shown in Table 1 is demonstrated
- explain the importance of indicators considering the global material requirements such as TMR as complements of DMI and DMC
- show the importance of determining indicators such as TMR or others regularly based on a sound methodology.

This paper is aimed on the one hand at practitioners who want to apply MFA for providing resource policy decision support and on the other hand at experts in resource and environmental policy who want to know what MFA can provide for them. The paper is also aimed at decision makers and experts, including the heads of environmental protection agencies, for getting their support for the further development and regular application of MFA indicators.

Table 1: National objectives concerning decoupling in Europe (EEA 2005a).

Country	Target	Document	Date
Austria	Increasing resource productivity by Factor 4	Austrian strategy for sustainable development	Endorsed by Austrian Council of Ministers on 30 April 2002
Belgium	Decoupling natural resource use from economic growth	Federal plan for sustainable development 2004–2008	September 2004
Denmark	Limit resource consumption to 25 % of current consumption	Denmark's national strategy for sustainable development: A shared future — balanced development, the Danish government	August 2002
Germany	Double energy and raw material productivity by 2020. In the long term, achieve Factor 4 improvement	German strategy for sustainable development	Passed by the Federal cabinet on 17 April 2002
Ireland	Progressive decoupling of economic activity from environmental degradation	Ireland's strategy for sustainable development: Department of the environment and local government	2002
Italy	Reduce TMR by 25 % by 2010, 75 % by 2030, and 90 % by 2050	Environmental strategy action plan for sustainable development, Ministry of the environment and land protection	Approved by the Inter-ministerial Committee for Economic Planning on 2 August 2002
Netherlands	Dematerialisation by a factor 2 to 4 in year 2030	Fourth national environmental policy plan	October 2001
Poland	Reduce material intensity by 40 % between 1990 and 2010	National environmental policy for 2003–2006	December 2002
Portugal	Reduce resource consumption by a factor of 1.5 in industrial companies	National strategy for sustainable development 2005–2015	July 2004

The paper is structured as follows

- different types of MFA and of MFA indicators are introduced
- a summary of current OECD and Eurostat activities and papers is provided
- MFA activities in different European countries are summarised
- complementary approaches proposed by the European Commission are discussed
- conclusions and recommendations for further activities are provided.

2 TYPES OF MFA AND MFA INDICATORS

This chapter provides an overview which types of MFA are in use in Europe to support resource and environmental policy development.

2.1 Economy-wide MFA

The basic accounting framework of MFA is the "economy-wide MFA". "Economy-wide material flow accounts are consistent compilations of the overall material inputs into national economies [extracted from the domestic environment or imported from other economies], the changes of material stock within the economic system and the material outputs to other economies or to the environment" (EUROSTAT 2007, p.4). The material flows are grouped in material categories. On the highest aggregation level four material categories are usually differentiated:

- Biomass
- Fossil fuels
- Metallic minerals / ores
- Non-metallic minerals

These material groups are then further subdivided. The Eurostat Standard Tables on economy-wide MFA differentiate 6 material categories on the 1-digit level, 30 material categories on the 2d-igit level, and 53 material categories on the 3-digit level (EUROSTAT 2007).

In the following indicators are described which are derived from economy wide MFA.

2.1.1 Physical Trade Balance (PTB)

The physical trade flows show all economic imports and exports of a nation/national economy for a certain year in terms of the mass flows of the imported and exported commodities (see Figure 1). Physical trade data are commonly derived from foreign trade statistics, where imports and exports are reported in monetary as well as physical units.

The Physical Trade Balance (PTB) as indicator is the difference between physical imports and physical exports:

PTB = Import - Exports

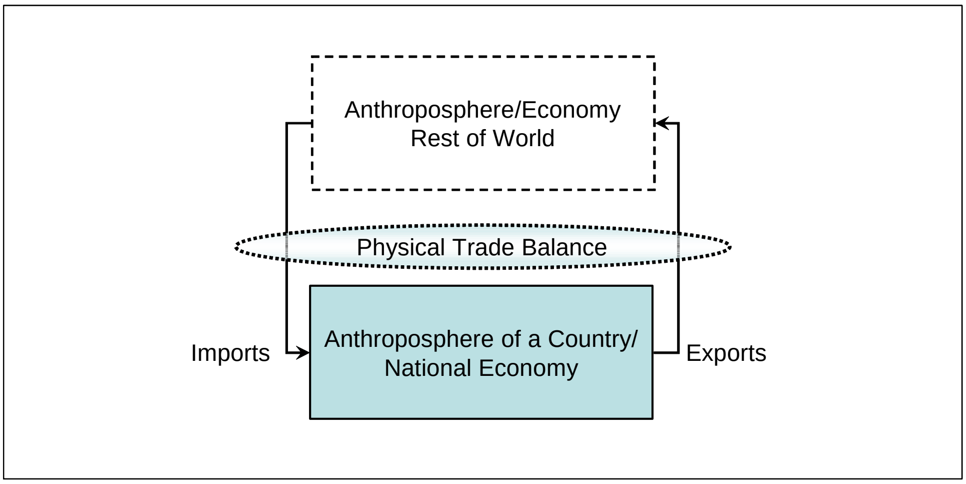

Figure 1: Scheme of a physical trade balance

As other MFA indicators, physical trade balances are compiled on a highly disaggregated level. The Austrian physical trade balance for example comprises 262 commodity groups (STATISTIK AUSTRIA 2007) which are then aggregated to 4-6 material groups.

A time series of the Austrian physical trade balances for example shows that not only fuel imports but also raw material imports (i.e. imports of primary goods) increased considerably in the period 1990 to 2006 (see Figure 2). A closer look at the raw materials (see Figure 3) reveals that the Austrian economy runs on an increased import of wood and above all metal ores.

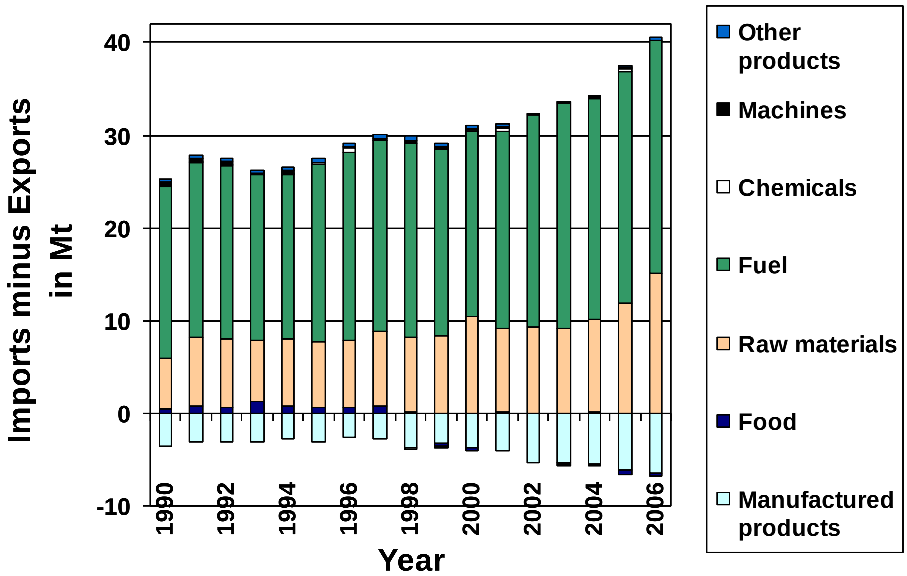

Figure 2: Aggregated Austrian physical trade balance (calculated from STATISTIC AUSTRIA *2007; personal communication: Sacha Baud, Statistik Austria, 27.09.2007)*

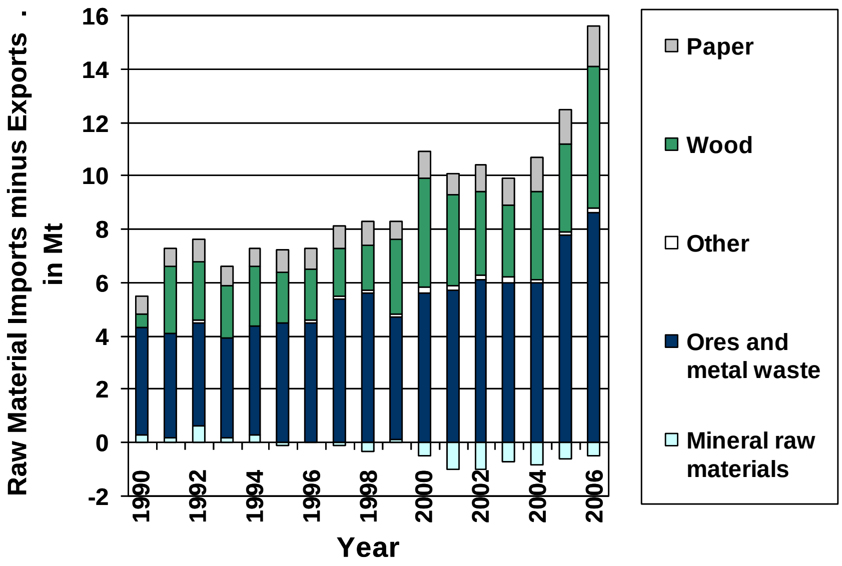

Figure 3: Austrian physical trade balance for raw materials (calculated from STATISTIC AUSTRIA *2007; personal communication: Sacha Baud, Statistik Austria, 27.09.2007)*

2.1.2 DE, DMI, DMC

Domestic Extraction (DE) is aggregated from a large number of items such as single crops harvested, fossil fuels extracted, single metal ores extracted etc. Economy-wide MFA takes detailed information from national statistical reporting and sums the information to aggregated groups and categories. DE includes tailings (metals are accounted for in gross ores), wastes produced during mining are considered as outputs from processing. Overburden or unused harvest residuals are considered as “unused extraction” and therefore not included in DE.

The depiction of Domestic Extraction over time can reveal important changes of the raw material basis of an economy. Figure 4 shows, for example, the development of annual extraction of metal ores for the world as a whole, for Europe and for Austria for the period 1985 to 2005. While in the latter country the extraction of ores saw a substantial decrease, the ore extraction in Europe stagnated and the ore extraction world wide increased at an average annual rate of 2,8 %.

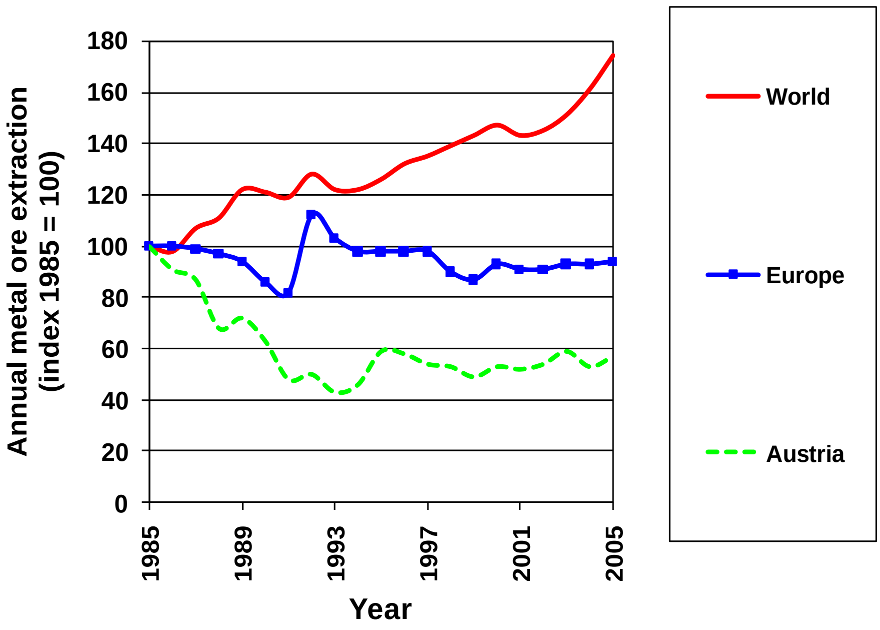

Figure 4: Development of Domestic Extraction of ores worldwide, in Europe and in Austria (calculated from SERI 2008)

Domestic extraction (DE) plus physical imports results in the DMI (Direct Material Input) of a nation/economy. Domestic material consumption (DMC) is derived by subtracting physical exports from DMI (see Figure 5). It has to be mentioned that the term “consumption” as used in DMC denotes “apparent consumption” and not “final consumption”. That is to say DMC represents all materials that entered the economic system and that remain in the system until they are later released to the environment as wastes and emissions. DMC therefore is also referred to as “domestic waste potential” of an economy. (WEISZ ET AL. 2006)

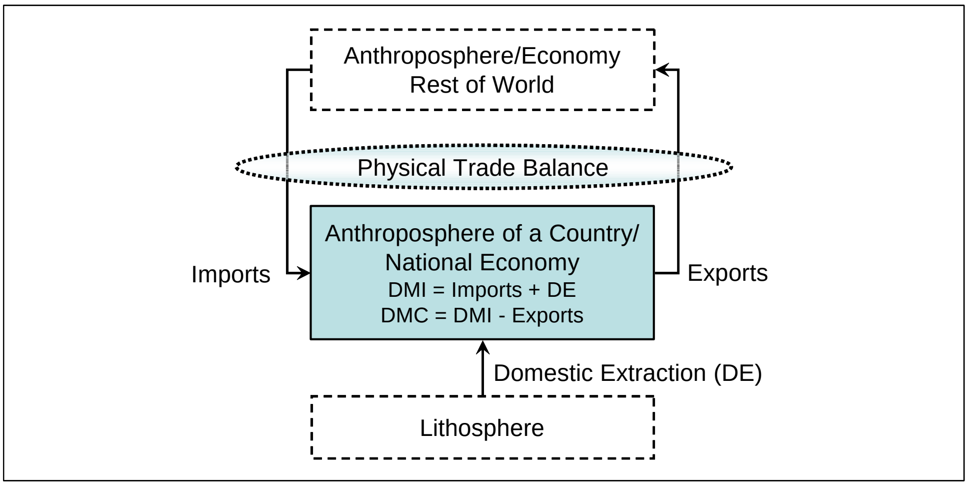

Figure 5: Scheme for determining DMI (Direct Material Input) and DMC (Domestic Material Consumption)

On the European Union member states level WEISZ ET AL. (2005) have calculated DMC and DMI for the year 2000 for 15 European countries and following material groups:

- Biomass
- Industrial minerals and ores (including metal based products)
- Construction minerals
- Fossil Fuels.

These 4 material groups are further sub-divided in 12 material groups. The structure of MFA then allows even further disaggregation following statistical classification schemes.

For Austria time series of DMC and DMI for the period 1960 to 2005 was prepared by Statistik Austria (PETROVIC 2007) for 6 material groups and further subcategories.

An example derived from this time series is the development of resource productivity in Austria as shown in Figure 6. It can be seen, that in contrast to the example shown in the Annex of the Thematic Strategy on the Sustainable Use of Natural Resource (EUROPEAN COMMISSION 2005b) resource productivity does not grow exponentially but rather stagnates in the last years.

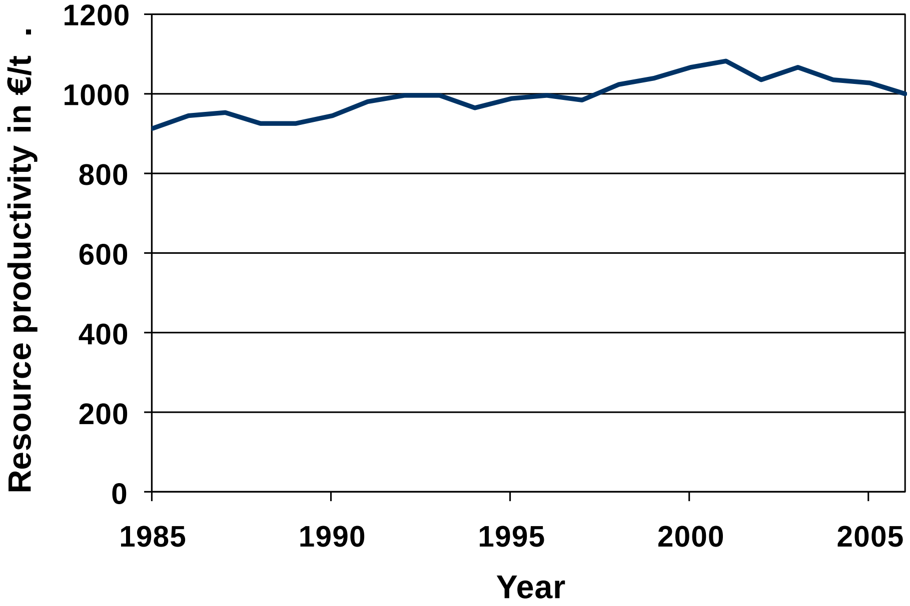

Figure 6: Development of Austrian resource productivity in terms of GDP/DMI (calculated from PETROVIC *2007 and* STATISTIK AUSTRIA *2008)*

2.2 MFA based on Input-Output-Tables

Within the large family of approaches for accounting and modelling material flows, methods of environmental Input-Output Analysis (eIOA) play a central role for performing policy-related MFA studies. eIOA allows to take a closer look on the material flows between the sectors of a national economy and to track product- and sector-specific developments of resource flows and resource productivity. Thereby, environmentally important sectors and products ("hot spots") can be identified and ranked. It further allows analysing implications for natural resource use of structural changes of the economy, as well as of changes in technology, trade, investments and consumption and lifestyles (GILJUM ET AL. 2008a).

The integration of material accounts in physical units into economic input-output models was first explored by LEONTIEF ET AL. (1982), in order to forecast trends in the use of non-fuel minerals in the US.

Today three basic eIOA approaches for constructing material flow models can be distinguished:

- Input-output-based material flow models can use a Monetary Input-Output Table (MIOT) extended by additional vectors of natural resource inputs in physical units.
- Physical Input-Output Tables (PIOTs) reflect all economic transactions in mass units (see Table 2) (GILJUM & HUBACEK 2008).
- Hybrid Input-Output Tables (HIOT) are intermediate forms which can be applied including both monetary and physical information in the interindustry flow table, with the most material intensive sectors being represented in physical units (see WEISZ & DUCHIN 2006; WEISZ 2006).

By using a MIOT as the core matrix, one can illustrate the economic responsibilities, which agents hold for inducing material extraction. A MIOT approach thus follows economic causalities, whereas a PIOT approach follows physical causalities (GILJUM ET AL. 2008a).

Table 2: Example of an Input-Output-Table – Z_{12} meaning flow from sector 1 to sector 2 (in the MIOT the flow is denoted in €/a, in a PIOT the flow is denoted in t/a)

	Receiving Sectors				
Providing Sectors	1	2	3	4	n
1		Z_{12}	Z_{13}	Z_{14}	Z_{1n}
2	Z_{21}		Z_{23}	Z_{24}	Z_{2n}
3	Z_{31}	Z_{32}		Z_{34}	Z_{3n}
4	Z_{41}	Z_{42}	Z_{43}		Z_{4n}
N	Z_{n1}	Z_{n2}	Z_{n3}	Z_{n4}	

2.2.1 Global Resource Accounting Methodology (GRAM)

The GRAM approach combines

- A Monetary Input-Output Model (MIOT) consisting of 36 country models (27 OECD countries (except Iceland, Luxemburg and Mexico) and 9 non-OECD countries (Argentina, Brazil, China, India, Indonesia, Israel, Russia, Singapore and Taiwan) with 48 harmonised sectors each
- connected by bilateral trade data (if no specific data is available the foreign trade data of OECD countries are also extrapolated for non-OECD countries)
- and material input data which translate the Euros/a (per sector per country) of import into tons of import plus tons of indirect material flows (GILJUM ET AL. 2008a).

The material input data are taken from the “MOSUS” (Modelling Opportunities and limits for restructuring Europe towards SUStainability) data set (GILJUM ET AL. 2008a). This data set now comprises data on resource use in about 200 countries for the years 1980 to 2005 by more than 200 raw material categories (SERI 2008).

GILJUM ET AL. (2008b) report, that following improvement of the GRAM-approach are necessary:

- Input-output tables need to be further disaggregate especially with respect to
  - the structure of neighbouring countries,
  - the structure of countries in Africa, Asia and Latin America, which have high levels of material extraction and export,
  - and environmental impact categories.
- Integration of additional trade data.
- Analyses of international production chains and structural paths.
- Extension of GRAM by other environmental categories such as energy-related CO2 emissions.

2.3 Global Material Requirements

Direct material indicators such as DMI and DMC focus on the specific socio-economic system and the materials entering and leaving the system. However, with increasing global integration, production processes are spread over the world and a global division of labour is established that concentrates production processes. In order to display the total raw materials required to provide goods for domestic final consumption, the materials used during the production process of traded goods have to be accounted and allocated to the country of final consumption. In MFA these flows are termed "indirect flows" and defined as follows: „[…] indirect flows are defined as the up-stream material input flows that are associated to imports but are not physically imported. […] Indirect flows are the 'cradle to border' inputs necessary to make a product (i.e., a good or a service) available at the border for import or export, excluding the mass of the product itself." (EUROSTAT 2001: p. 22f)

In MFA there are mainly two approaches to calculate these upstream material requirements or indirect flows associated to imports and exports: the product-based approach resulting in the TMR, and the input-output-based approach which calculates Raw Material Equivalents (RME).

While the methodology for determining domestic extraction and physical import flows to a national economy seems to be already quite advanced in most European countries, the biggest challenge in the further development of MFA is the determination of indirect flows connected to the material imports. A concise methodology for determining the indirect flows is needed.

2.3.1 TMR

One approach that calculates the global material requirement is the account for the TMR, the "Total Material Requirements". The TMR theoretically considers all used and unused extraction associated to the production of imported goods and is defined as DMI plus indirect flows (used and unused extraction) associated to imports. (see Figure 7). However, it has to be mentioned that TMR puts strong emphasis on the unused extraction whereas the accounting for materials used in the production process of finished goods is rather limited.

In environmental terms, it is a proxy for potential environmental pressures associated with the resource extractions. Since all these material inputs will sooner or later be transformed to material outputs (i.e. emissions, waste) TMR also constitutes a proxy for potential future environmental pressures, on a life-cycle-wide basis, to the domestic as well as foreign environment.

To estimate the waste and emissions arisings in foreign countries associated to all imports is a very time consuming effort. Therefore TMR has been estimated only for a limited number of countries and in those cases also only for one year. Therefore few time series exist with respect to TMR. An institution which has put much effort in estimating the TMR is the Wuppertal Institute which for example has produced the results shown in Figure 8.

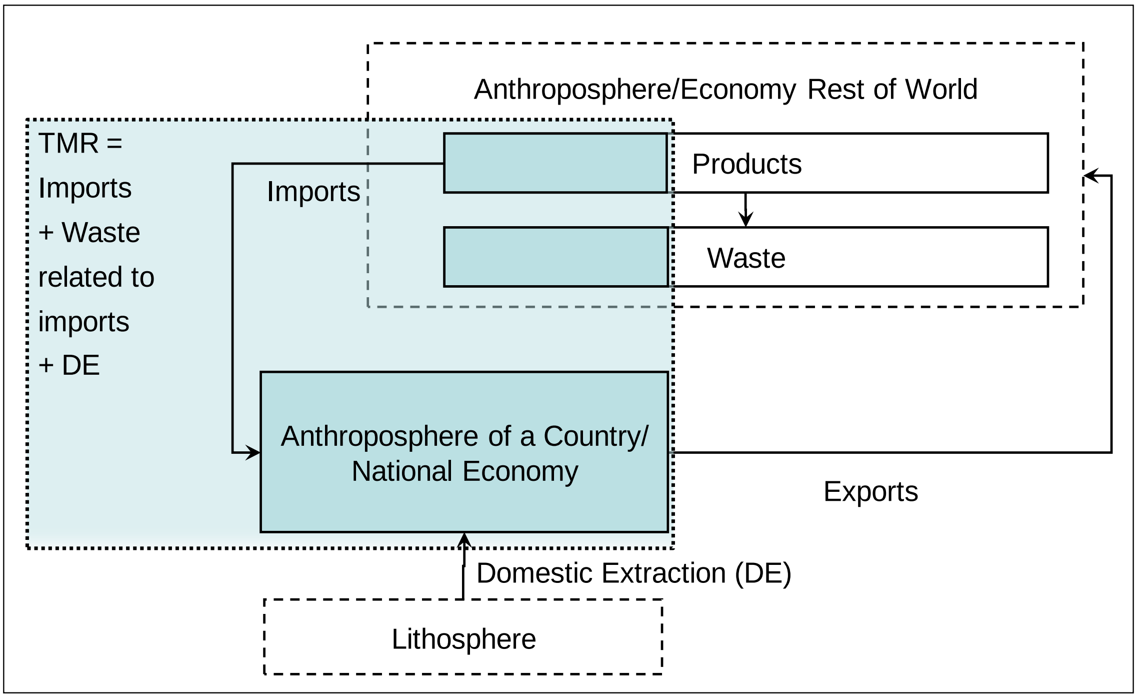

Figure 7: Scheme for calculating the Total Material Requirement (TMR) for a nation/economy

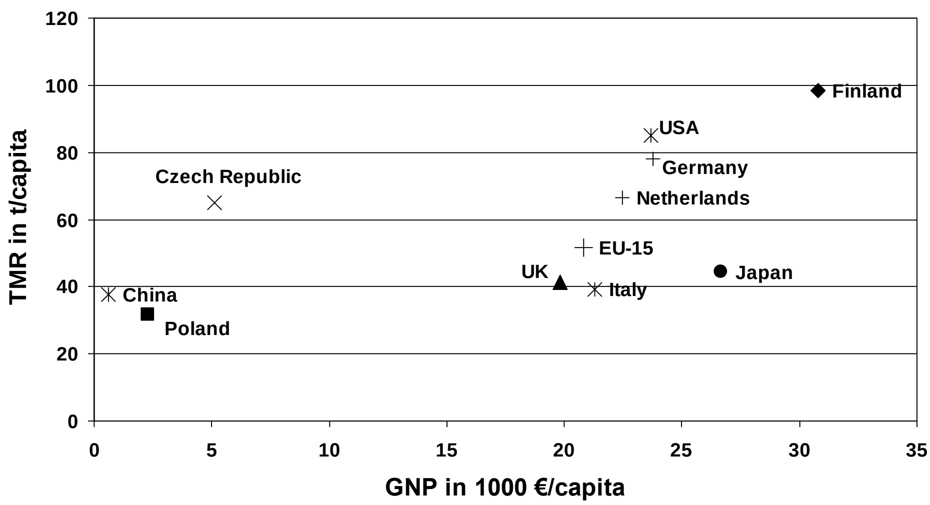

*Figure 8: Total Material Requirement (TMR) versus Gross National Product (GNP) for different countries and EU-15 (*BRINGEZU *2003).*

The methodological approach to calculate the TMR was developed at the Wuppertal Institute in Germany and is based on Material Intensity Analysis (MAIA) (SCHMIDT-BLEEK ET AL. 1998). MAIA is an analytical tool to assess the material inputs along the whole life-cycle, including direct material inputs and the so-called „ecological rucksack“ (RITTHOFF ET AL. 2002; SCHMIDT-BLEEK 1992, 1994). The ecological rucksack can be defined as „the total sum of all materials which are not physically included in the economic output under consideration, but which were necessary for production, use, recycling and disposal. Thus, by definition, the ecological rucksack results from the life-cycle-wide material input (MI) minus the mass of the product itself“ (SPANGENBERG ET AL. 1998, p. 15). To use the terms proposed by EUROSTAT, the ecological rucksacks of imported products equal their indirect flows and consist of both used and unused materials. The so-called „rucksack-factor“ is the ratio of the materials included in the ecological rucksack and the produced good (ton per ton) (GILJUM ET AL. 2008a).

This calculation methodology is mainly suitable for the calculation of indirect flows associated to biotic and abiotic raw materials and products with a low level of processing. To calculate indirect flows for semi-manufactured and finished products by applying this methodology requires the collection of large amounts of data for every product under consideration. Therefore, indirect flows have so far been calculated for a very limited number of processed biotic and abiotic products (GILJUM et al. 2008a).

2.3.2 Raw Material Equivalents (RME)

Another approach in accounting for indirect flows associated to imports and exports is following the concept of “Raw Material Equivalents” (RME) defined as follows: “[…] up-stream indirect flows [are] expressed as the Raw Material Equivalents (RME) of the imported or exported products (less the weight of the imported or exported product). The RME is the used extraction that was needed to provide the products.“ (EUROSTAT 2001: p. 22f) And later: „Indirect flows associated to imports and exports should be calculated using input-output techniques in the same way as e.g. ‘embedded’ energy is calculated, maybe even based on hybrid – i.e. mixed physical/monetary – input-output tables (for the principles see e.g. Miller & Blair 1985). As such input-output tables are not usually available for a nation’s trading partners, the indirect flows associated to imports may be estimated using the national input-output tables. This assumes that imported products are produced in the same way (materials, energy, technology) as domestically produced products.“ (EUROSTAT 2001: p. 24)

Starting from the RME of imports and exports, several indicators can be derived that complement direct indicators. The Raw Material Consumption (RMC) for example equals DE plus direct imports plus RME of imports minus direct exports plus RME of exports. The RMC represents the total amount of used extraction that was globally used in order to provide goods of domestic final demand. RMC can be understood as representing the domestic material standard of living.

RME accounts use Input-Output Tables and trace material flows through the economy along inter-sectoral deliveries. By that, RME accounts follow a systemic approach by considering the whole economy. Second, IO tables are usually provided by Statistical Offices which allows RME accounts to connect to national reporting and time series analysis. However, the method is still under development and so far only applications on selected countries are available.

RME accounts so far were conducted for Germany (SCHOER & SCHWEINERT 2005, SCHOER 2006), the Czech Republic, and Austria (WEISZ et al. 2008). First results were presented at the ConAccount Conference in Prague in 2008 (http://www.conaccount.cuni.cz/index.php). Additionally, an EU project EXIOPOL is currently working on an environmentally extended Input-Output database (among other tasks) for Europe and other regions.

In order to obtain estimates of the indirect flows, Eurostat supports the development of DMC expressed in RME (raw material equivalents), often called "DMC_{RME}". This approach appears, at this time, to be more suited to implementation within the statistical system than the TMR[1].

2.4 National MFA and Substance Flow Analysis (SFA) based on Process-Flow-Sheets

In addition of producing resource indicators MFA also allows drawing more general (see Figure 9) or more detailed pictures (see Figure 10) of the material flows through a country or national economy. As means of substance flow analysis these flow sheets show the flows and stocks of a certain substance (that is, a chemical element like e.g. cadmium) in an economy.

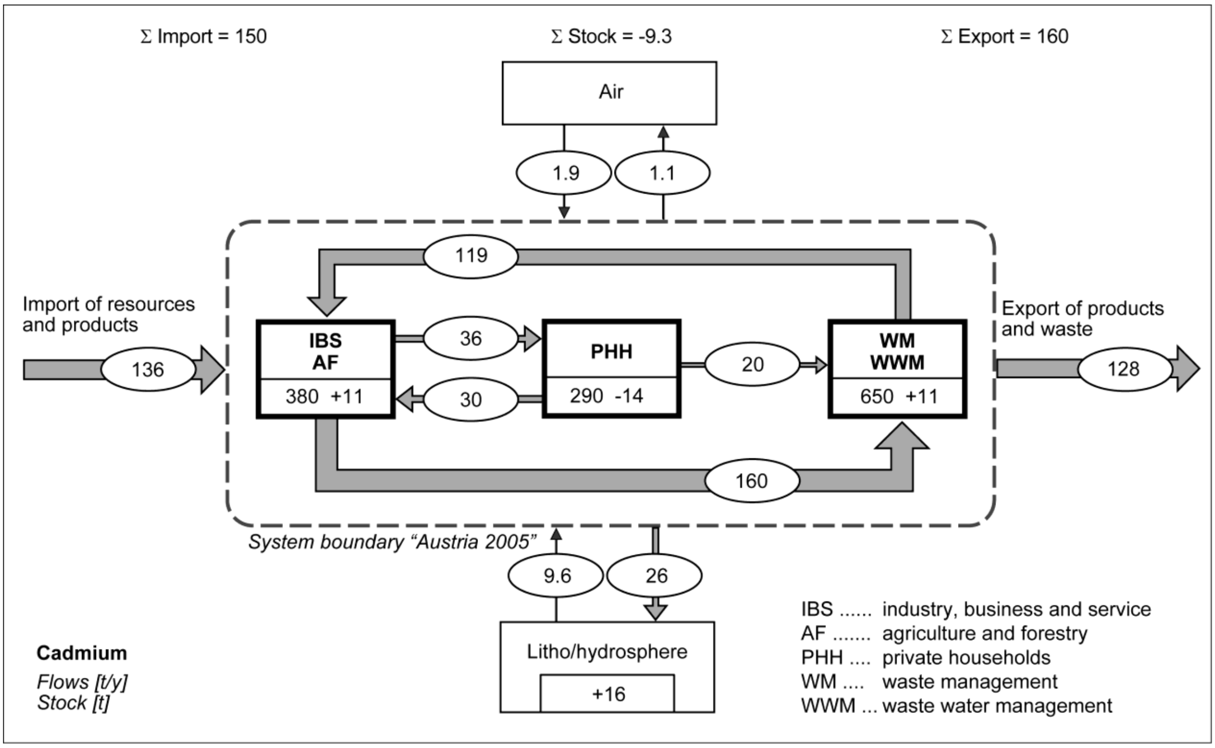

Figure 9: Simplified Cadmium-Flow-Analysis of the Austrian economy (UMWELTBUNDESAMT 2009)

[1] Personal communication Eurostat, 10.09.2009

During the last 10 years many MFA studies focusing on certain materials, goods, substances or specific policy questions have been performed. These allowed to:

- Integrate information and data from many different scientific areas
- evaluate if the system runs in the way desired or if action should be taken
- visualise the dimension of the different flows e.g. within the economy as compared to emissions
- identify accumulation processes
- determine antropogenic stocks
- identify focus areas for further action

No example is known of process flow sheet based MFA repeated every year for a national system. Therefore it can be assumed that this work is not or only rarely done by statistical offices but mostly by universities or private consultants, however, in many cases based on data from the statistical office.

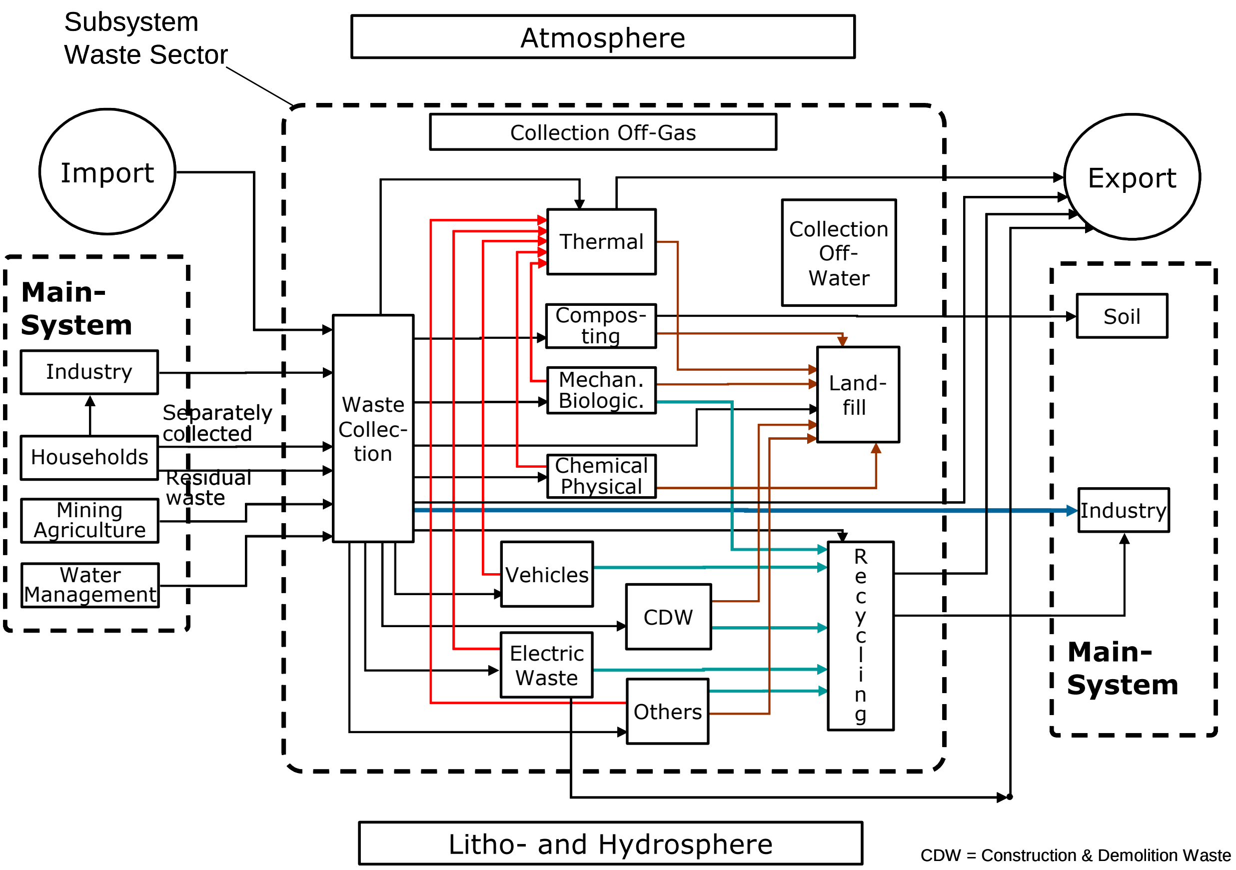

Figure 10: Example of a more complex MFA - Flow sheet of the sub-system "Austria Waste Management Sector" as part of a cadmium-, lead and mercury flow analysis (not shown are the emission flows into air and water and the actual quantities)

The project Forwast combines a PIOT with substance flow analysis (SFA). Here every economic sector produces a typical product of a typical chemical composition. The mass of this product is then distributed to the other economic sectors according to the circumstances of the real economy to be modelled. This allows to simulate the output- and input-flows of the economic sectors not only in terms of typical products put also in terms of their chemical components.

3 OECD AND EUROSTAT WORK ON MFA

In 2001 Eurostat issued a methodological guide on economy-wide material flow accounts (EW-MFA) and derived indicators (EUROSTAT 2001), which set many of the standards and definitions used in here. It introduced a system of national material flow accounts and balances based on the definitions shown in Figure 11. It also provides a detailed classification of the different mineral-, biomass- and import materials as well as types of emissions to water and dissipative material flows.

INPUTS (origin)	OUPUTS (destination)
Domestic extraction Fossil fuels (coal, oil…) Minerals (ores, sand…) Biomass (timber, cereals…) **Imports**	**Emissions and wastes** Emissions to air Waste landfilled Emissions to water **Dissipative use of products and losses** (fertiliser, manure, seeds, corrosion)
DMI – direct material inputs	***DPO – domestic processed output to nature***
Unused domestic extraction From mining /quarrying From biomass harvest Soil excavation	***Disposal of unused domestic extraction*** From mining /quarrying From biomass harvest Soil excavation
TMI – total material input	***TDO – total domestic output to nature***
	Exports
	TMO – total material output
Indirect flows associated to imports	
TMR – total material requirements	***Net Additions to Stock*** Infrastructures and buildings Other (machinery, durable goods….)
	Indirect flows associated to exports

Note: excludes water and air flows (unless contained in other materials)

Figure 11: Composite economy wide material balance with derived resource use indicators (EUROSTAT 2001)

With regards to data reporting and quality, Eurostat is currently proposing an environmental accounts reporting regulation (text with relevance for the European Economic Area) covering the input side of EW-MFA. This potentially new legal requirement will in the long term provide better data reporting of EW-MFA data for European countries which will also require data quality reports[2].

[2] Personal communication Eurostat, 10.09.2009

In 2008 OECD (Organisation for Economic Co-operation and Development) published a series of 4 documents on "Measuring Material Flows and Resource Productivity", which had been prepared based on extensive consultation process among the experts of the OECD-member states and international consultants:

- The synthesis report (OECD 2008a) gives an overview of material flow analysis and its resource policy implications, and summarises the results of the other four documents
- The **OECD guide on Measuring Material Flows and Resource Productivity** (OECD 2008b) "describes the full range of material flow approaches and measurement tools, with a focus on the national level and emphasis on areas in which practicable indicators can be defined…. It includes an overall framework of material flow analysis, a description of different kinds of measurement tools, a discussion of those issues and policy areas to which MFA and material indicators can best contribute and 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."
- The **Accounting Framework** (OECD 2008c) "provides a theoretical and technical description of the concepts and methodologies of material flow accounting."
- The **Inventory of Country Activities** (OECD 2008d) "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." The summary tables of this OECD document are shown in Annex A of this paper for the European OECD countries. This provides the frame for the country descriptions in the next chapter.

A fifth OECD document on **"Implementing National Material Flow Accounts"** is under preparation jointly by OECD and Eurostat. This will "provide practical guidance to assist countries in implementing national material flow accounts" (OECD 2008a).

4 MFA IN EUROPEAN COUNTRIES

The material flow accounting framework of national statistical offices in general covers 2 kinds of accounts:

- economy-wide material flow accounts (EW-MFA) or balances and
- physical input-output tables (PIOTs).

The economy-wide material balances give an aggregated description of the material input and output of socio-economic systems (including stock changes). PIOTs provide a comprehensive description of material flows both between environment and socio-economic system and within the latter.

The tables in Annex A summarise the status of Material Flow Analysis in a number of European countries. Table 5 shows that most European OECD countries have a Economy-Wide Material Flow Accounting system, some prepare Physical Input-Output Tables and/or substance flow analysis. Also national resource accounts or a National Accounting Matrix including Environmental Accounts (NAMEA) are prepared in many European countries. Table 6 shows which material flow indicators are determined in 17 European countries. The DMI is calculated in most, the DMC in all and the TMR in about half of these countries.

4.1 Austria

Austria initiated activities on Material Flow Accounting in 1991 as part of the country's official statistics (work on Environmental Accounting) and following a request by the Ministry of Environment in 1989. Work is also carried out by academics. It covers economy-wide material flow accounts (EW-MFA), physical input-output tables (PIOTs), substance flow analysis (SFA) as well as National Accounting Matrix including Environmental Accounts (NAMEAs) (OECD 2008d).

Lead institutions are Statistics Austria and the Institute of Social Ecology in Vienna (IFF-Vienna; University of Vienna and Klagenfurt). Other institutions involved are: the Federal Ministry of Agriculture, Forestry, Environment and Water Management; the Vienna University of Technology, and Sustainable Europe Research Institute (SERI), a private research institute (OECD 2008d).

Economy-wide material flow accounts are compiled in accordance with the Eurostat methodology using the classification of the Eurostat Standad Tables (PETROVIC 2007). The EW-MFA are updated annually. Most recent data refer to 2005 (published 2007).

Further work on economy-wide MFA as well as on PIOTs is carried out by the IFF-Vienna. Studies on economy-wide MFA are conducted for the EU and selected developing countries in time series, a global MFA dataset is compiled, and cross-country comparisons are conducted and analysed. Work on PIOTs includes the establishment of a highly aggregated PIOT for Austria, as well as conceptual and empirical work on physical input-output analyses and their applications (raw material equivalents and sectoral analysis). Projects on MFA and PIOTs are also undertaken at SERI. The projects include a global material flow time-series as well as work on concepts and applications of PIOTs, in particular, to integrate PIOTs into monetary Input-output models (OECD 2008d).

Substance Flow Analysis (SFA) has been done by Statistics Austria, different consultancy firms and the Group of Waste and Resources Management of the Vienna University of Technology. Initiated by government agencies, the following SFA of the Austrian economy were prepared (in brackets, the number of processes simulated to represent the whole economy):

- 1997 - Zinc (11);
- 2003 - Sands and stones (13), Iron ore and iron (11), Crude Oil (8), Coal (10), Wood and paper (9), Other biomass (9), Nitrogen (16), Aluminium (19), building materials (16) and the flows of the substance Aluminium, Iron, Carbon and Nitrogen in the building sector (16);
- 2006 - Copper (8) (OECD 2008d);
- 2008 – Lead, Mercury, Cadmium (16).

The recent SFA on lead, mercury and copper for example compares the flows and stocks of these heavy metals within the Austrian economy to the emissions to air, water and lithosphere. A special emphasis was put to simulating the heavy metal flows within the waste sector and within the recycling material flows. Following hot spots for further resource and environmental policy actions were identified:

- A high level of uncertainty of how heavy metals in waste streams are related to heavy metals in the original products;
- Uncertainties if current analytical methods for determining the heavy metal concentration in bottom ash of waste incineration plants identify the full concentration of these heavy metals (these uncertainties being one possible explanation why a considerable share of the heavy metals from consumer batteries seem to be missing in the substance balances);
- The big amount of lead released into the environment by sports shooting, hunting and fishing;
- The big mercury stock in dental amalgam and supposedly in old-mercury-fever-thermometers still kept in households;
- A considerable amount of mercury released by cremation and burials;
- The big amount of heavy metals released into the environment from top-soils by eluviation.

An interlinked National Accounting Matrix including Environmental Accounts (NAMEA) (covering output, value added, employees, material flows, final energy consumption, environmental protection expenditure for air and waste, air emissions, eco taxes and hazardous waste) is prepared by Statistics Austria and Umweltbundesamt. Information on environmental accounting are available via the web page: www.umweltgesamtrechnung.at.

Data from Material Flow Accounts are regularly (annually) published by Statistics Austria on its website:
http://www.statistik.at/fachbereich_umwelt/materialfluss.shtml .

Data from EW-MFA are used to derive selected material flow indicators among which: Direct Material Input (DMI), Domestic Material Consumption (DMC), Domestic Resource Dependency (DRD), Physical Trade Balance (PTB), and Net Additions to Stock (NAS).

For Austria time series of DMC and DMI for the period 1960 to 2005 was prepared by Statistik Austria (PETROVIC 2007) and published for the following 6 material groups:

- Biomass and biomass products
- Metal ores and concentrates, processed metals
- Non metallic minerals (primary and processed)
- Fossil energy carriers (primary and processed)
- Other products
- Waste imported for final treatment and disposal

DMI, DMC and DRD are part of Austria's indicator-report for the monitoring of sustainable development compiled jointly by Statistics Austria and the Federal Ministry of Agriculture, Forestry, Environment and Water Management.

4.2 Basque Region and Spain

The Basque Country (Spain) is one of few examples where the material flow accounting (MFA) has been developed on a regional level. In 2001, the Environmental Economics Unit of the Basque University, together with the Public Society of Environmental Management (Ihobe), started working on this field and calculated the Total Material Requirement (TMR) of the Basque Country. As a result of that first colaboration, the document called “Total Material Requirement of the Basque Country”[3] was published in 2002. Thanks to that working line, a complete balance on the material flows in the Basque Country during the 1990-2005 period has been prepared. The information of the balance is updated every year.

In order to create the MFA of the Basque Country, advice given by EUROSTAT and the European Environment Agency was followed. This methodology has been adapted to be applied at subnational level (especially, when it comes to accounting for the commerce with the rest of the Spanish regions).

[3]http://www.ingurumena.ejgv.euskadi.net/r49-6172/en/contenidos/libro/ntm/en_pub/adjuntos/ntm.pdf

These are the main indicators that come from the MFA of the Basque Country: Total Material Requirement (TMR), Direct Material Input (DMI), Domestic Material Consumption (DMC), Total Material Output (TMO), Total Domestic Output (TDO), Domestic Processed Output (DPO), Physical Trade Balance (PTB) and Net Additions to Stock (NAS).

On the other hand, the Basque Government has included the TMR indicator in the list of the main indicators of the Basque Environmental Strategy for Sustainable Development 2002-2020 (BESSD). Besides, the Basque Government is using MFA and the above mentioned indicators for following up some of the objectives of the four-year programmes which carry out the BESSD. Thus by means of MFA the progress of the 1st and the 2nd Environmental Framework Programmes towards their objectives: “to maintain the *per capita* Total Material Requirement of 2006 in the level of 1998” and “to maintain the resource consumption effectiveness of 2010 in the level of 2001” (Basque Government, 2002 and 2007) is monitored.

The information contained in this MFA has also been used for identifying material intensive activities and products (production of tin capsules) and for analysing the environmental impact related to these materials.

The structure of the information in the MFA of the Basque Country is currently being developed, in such a manner that it is compatible with the economic accounting (Input-Output tables).

In Spain, the National Statistics Institute started preparing the Material Flow Analysis (MFA) in 2003. The MFA has been prepared following the methodology proposed by EUROSTAT. The MFA provides a complete balance of the material flows of the Spanish economy for the period of 1996-2005, including indicators of material inputs, outputs and consumption indicators. The Spanish MFA are updated periodically. The last update was made in July, 2008.

4.3 Germany

Overview

Germany is among the most experienced countries in MFA and has developed a comprehensive Material and Energy Flow Information System (MEFIS), based on a MFA framework and on physical input-output tables (PIOTs). Work is carried out both by the government and by academics. Government work was initiated in 1993 as part of the country's official statistics and as part of work on Environmental Economic Accounting. Work on economy-wide material flow accounts (EW-MFA) started in 1993, mainly at the academic level.

The German Federal Statistical Office (DESTATIS) and its Division for Environmental Economic Accounting is the lead institution responsible for MF accounts. The work is carried out in co-operation with nongovernmental research institutes, and has benefited from financial support by Eurostat. Among other institutions involved is the German Federal Environment Agency (UBA Germany). UBA Germany is engaged in research on resource-indicators, derived from material flow (further information: see passage ‘outputs and use’).

Germany also contributes to international work steered by the London Group on Environmental Accounting and to collaborative work in Europe steered by Eurostat and the European Environment Agency (EEA) and its Topic Centre on Resource and Waste Management. Together with Austria, Japan, the Netherlands and the USA, it has actively participated in the joint international research project on material flows that led to two key publications by the World Resource Institute in 1997 and 2000. Bilateral co-operation in the field of Environmental Economic Accounting exists with Korea.

Characteristics and Scope

The German System of Environmental Economic Accounting is fully compatible with the System of National Accounts (SNA) and with the System of Integrated Environmental and Economic Accounts (SEEA). The physical flow accounts, structured around physical input-output tables, are the most developed part of it.

Physical Input-Output Tables (PIOTs):

The first German PIOTs, compiled in the mid-1990’s with data for 1990, were also the first PIOTs ever compiled in the world (STAHMER ET AL. 1996). They mirror the monetary input-output tables (MIOTs) of the national accounts and broaden their scope by adding material flows between the economy and the environment. The PIOTs are broken down by about 60 economic production and consumption activities and by type of materials. PIOTs are compiled for selected years only (i.e. 1990 and 1995) and are supplemented with a number of sub-modules that are updated annually. These sub-modules include economy wide material flow accounts as well as a number of NAMEA-type accounts: energy flow accounts, primary material flow accounts broken down by 72 production branches and private households and by raw materials categories distinguishing biotic and abiotic materials, water flow accounts, air emission accounts, waste flow accounts (up to 1995 only), regional physical flow accounts. This is further supplemented by a number of other NAMEA-type accounts covering for example built-up and traffic areas, transport (person kilometres, tonnes kilometres), environmental taxes, environmental expenditures.

Economy-wide Material Flow Accounts (EW-MFA) have first been compiled in the mid-1990s for the years 1993-2000. They have recently been revised and complemented with accounts for 1960, 1970, 1980, and 1990 for the former territory of the Federal Republic of Germany, and with accounts for 1991-2002 for the current territory. Annual updates are planned in future.

The accounts cover the whole physical economy and their system boundaries are fully compatible with those for PIOTs. Conceptual differences with other European MF accounts were removed thanks to a study carried out with support from Eurostat. Lessons from this study have been grouped in a "National Handbook: Material Flow Accounts“ that builds on the Eurostat guide and also covers the development and calculation of MF indicators (publication forthcoming).

Outputs and Use

Publication: Data from MF accounts are regularly published by DESTATIS (various publications). MF indicators are included in "Environmental Data for Germany. Practicing Sustainability – Protecting Natural Resources and the Environment" published jointly by UBA Germany, DESTATIS and the Federal Institute for Geosciences and Natural Resources (BGR) and freely available on the web (German Federal Environment Agency et al. 2007). Various publications on specific issues related to MF accounts are also published by UBA Germany and the Wuppertal Institute. For instance, in early 2007, UBA published a study about the example of coltan extraction in the Democratic Republic of Congo, to explore how the demand for rare metals intensifies armed conflicts and presents possible solutions (BEHRENDT ET AL. 2007).

Indicators: Data from EW-MFA are used for compiling selected indicators among which: Direct Material Input (DMI), Domestic Material Consumption (DMC), Physical Trade Balance (PTB), Domestic processed output (DPO), Net additions to stock (NAS), and raw materials productivity (GDP/(DMI-biomass)). The indicators are calculated by DESTATIS and are updated on an annual basis. The indicator on “raw materials productivity” is defined as the ratio between Gross Domestic Product (at constant prices) and the sum of domestic abiotic (i.e. non-renewable) raw material extraction (used) and imports. It has similarities with indicators on labour and capital productivity, and describes the efficiency with which “non-renewable raw materials“ are used in the national economy. The DMI is derived by the simple addition of all raw materials provided for production and consumption, independent from the type of raw materials, measured in tonnes. In Germany, the minerals sand and gravel have a large share of the domestic excavation of raw materials and dominate the DMI, while other environmentally relevant raw materials such as copper, whose total volume/weight is comparatively small, play a marginal role.

In 2006 the IFEU-Institute, Heidelberg, started a research project, commissioned by UBA Germany. The objective of the research project is to further develop and supplement the existing indicator by considering the profiles of the environmental impacts associated with various raw materials. Furthermore, the improved indicator (indicator set) should guarantee more transparency and be practicably applied with respect to data availability and communication, resulting in a more effective information on the environment and sustainable development.

Another research project commissioned by UBA Germany is the further development of the indicator Direct Material Input (DMI) by DESTATIS. Its aim is to complement the actual data with a resource indicator in raw material equivalents to include “ecological rucksacks” of imported goods.

Links to policies and objectives: The raw materials productivity is one out of 21 national key indicators for sustainable development defined in the National Strategy for Sustainable Development “Perspectives for Germany: Our “Strategy for Sustainable Development” adopted by the German Federal Government in April 2002 (FEDERAL MINISTRY FOR THE ENVIRONMENT 2002). The strategy outlines 21 targets or objectives to which the key indicators can be linked. The targets indicate desirable policy directions and their achievement is voluntary. One of these targets is the doubling of the raw materials productivity between 1994 and 2020. “By 2020, we should aim for an approximate doubling of energy- and raw materials productivity in relation to 1990 and 1994 respectively. In the long term, the improvements in energy and raw materials productivity should be guided by the "Factor 4 vision" (FEDERAL MINISTRY FOR THE ENVIRONMENT 2002).

The Wuppertal Institute for Climate, Environment and Energy has actively contributed to the international promotion of MF related studies, and has carried out MF projects for the European Commission (DG Environment, Eurostat) and the European Environment Agency (EEA) and its Topic Centre on Resource and Waste Management. Together with research partners in Austria, Japan, the Netherlands, and the United States of America, it has actively participated in the joint international research project on material flows that led to two key publications co-ordinated by the World Resource Institute in 1997 (RADERMACHER 1998) and 2000 (WALDMÜLLER 2001). The Wuppertal Institute is the co-ordinator of ConAccount, "Coordination of Regional and National Material Flow Accounting for Environmental Sustainability", an international network of research institutions working on Material Flow Analysis (MFA). ConAccount was set up in May 1996 and supported financially by the European Commission (DG Environment) during the first phase of its existence until the end of 1997. The co-ordination of the ConAccount network is done in close co-operation with the Institute for Interdisciplinary Research and Continuing Education (IFF) in Vienna, the Centre of Environmental Science of Leiden University (CML), and Statistics Sweden.

The aim of ConAccount is:

- to support the exchange of information between scientists and researchers developing MFA and users of MFA results
- to provide the basis for the development of a coherent framework of a MFA methodology, and
- to promote the use of MFA for statistics and policy.

A first R&D agenda was defined in 1997 and supported with technical workshops and conferences. Today, ConAccount has about 100 participants providing information about their activities. This is done through an interactive registration system whose current version was established (February 2000) with the support of the European Environment Agency. Recent publications on MFA from the Wuppertal Institute include issues such as the Calculation of the Material Input Per Service unit (RITTHOFF ET AL. 2002), Globalisation and the Shifting Environmental Burden (SCHÜTZ ET AL. 2004), Resource Use in European Countries (MOLL ET AL. 2005), the Sustainable Use and Economy-wide Management of Resources (BRINGEZU 2006), and the Sustainable Use of Biomass (BRINGEZU ET AL. 2007).

4.4 Ireland

MFA has been developed in Ireland through a number of projects undertaken by the Central Statistics Office, academics and consultants and primarily funded by the Environmental Protection Agency. Specific projects include:

1. A demonstration MFA for Ireland was undertaken by the Clean Technology Centre for the data year 2000 published in 2006 (O'LEARY & CUNNINGHAM 2006).

2. An Economy-Wide MFA and derived indicator set for Ireland was undertaken by EnviroCentre, Best Foot Forward and the University of Limerick for the data year 2003 published in 2008. This project also included an eIOA and Ecological Footprint analysis. An EW-MFA was also calculated for Northern Ireland (a region of the UK) and both analyses integrated to form an all-Ireland model and indicator set. (CURRY ET AL. 2008).

3. The Central Statistics Office have recently produced a time series of EW-MFA from 1994-2007 which will be published shortly with the intention of updating annually.

Additional work on environmental accounting has been undertaken by ESRI (Economic and Social Research Institute) which includes environmental accounts for waste, water and emissions to air from 1990-2005, although the waste and water accounts are limited in scope.

Comhar – Sustainable Development Council has also published recommendations on a Sustainable Development Indicator set for Ireland which includes the set of MFA derived indicators (MAGUIRE & CURRY 2007) to inform national policy and actions on resource use and sustainable development.

4.5 Italy

Realizations of the Italian Statistical Office (ISTAT) in the EW-MFA field (ISTAT 2000, 2003, 2004)

ISTAT realised the main indicators related to the Italian Material Flows Accounting for the period 1980-2004, calculated according to the schemes of the satellite account EW-MFA (Economy-wide Material Flow Accounts) developed in Eurostat. The satellite account is consistent with the concepts and the fundamental schemes of the European System of the accounts SEC95, as well as with the guide lines adopted by the international organisms for the development of an integrated environmental and economic accounting system. The satellite account describes the overall use of natural resources from the socio-economic system in terms of physical mass of the materials put in motion; the latter are expressed in tons, a measure which is common to all the flows and meaningful in an ecological perspective.

In particular the data published by ISTAT describe, with reference to an articulated framework of accounts coherent and complete, the following flows:

- the withdrawals of natural resources directly effected on the Italian territory, to exclusion of the quantities of air and water not incorporated in products;
- the direct exchanges of materials with the rest of the world;
- the flows of materials indirectly necessary to the production of the imported and exported goods, not incorporated in such goods.

The sequence of accounts, from which the indicators are derived, finds a moment of synthesis in the overall balance of the material flows (inputs and outputs), of the national socioeconomic system. Such a balance has been so far realized with reference to 1997, and serves as a benchmark for the aggregated indicators time series. For that year the complete sequence of the accounts has been realized, including those related to the output towards the natural environment and the man-made stocks (capital, durable goods, landfilled waste).

In particular ISTAT calculated on annual basis the Italian direct material input and domestic material consumption (DMI and DMC), total material requirement and consumption (TMR and TMC), as well as the Italian physical trade balance (PTB), both excluding and including indirect flows.

As a result of the compilation of the material balance, ISTAT calculated for 1997 the Italian domestic processed output (DPO) and net additions to stocks (NAS), both as balance and directly measured.

Materials extracted from the territory of the country inputs are classified as follows:

- biomass from agriculture, forestry and fishing (there is no data on hunting);
- Fossil fuels;
- Minerals (metal ores, industrial and construction minerals).

Imports of materials are split between raw materials plus semi-manufactured products (intermediate consumption) and finished products (final use). Within both of these categories, material flows are classified as biomass, fossil fuel, mineral or composite products. Materials of the packaging containing the imported products are not separately accounted for.

Unused materials cover minerals (mining & quarrying overburden), biomass (harvesting losses) and soil (excavated for construction activities).

Memorandum items for balancing cover oxygen for combustion and respiration, nitrogen for combustion, other air for natural decomposition and other industrial processes and drinking water for livestock.

At the different levels of the Italian MFA framework, the material flows are classified according to the European nomenclatures: CN (external trade), EWC (waste), NACE (industries), and PRODCOM (production), etc.

Data on domestic extraction of fossil fuels and minerals, except for marine salt (Ministry of finance) and construction minerals (see below), come from ISTAT’s surveys, that are combined with data from the Ministry of industry and other sources. Estimates of the domestic extraction of construction minerals are based both on a joint ISTAT-Ministry of industry’s survey on quarries (and peat fields, incomplete set of data) and the PRODCOM survey (data from 1998 onwards). Also information of the Italian Institute for Environmental Protection and Research (ISPRA) on the reuse of excavated soil is used along with ISTAT surveys on building activities.

Data on domestic extraction of biomass mostly come from ISTAT's surveys that are published in either in specific Italian statistical yearbooks (agriculture and forestry, including non market gathering) or in the general statistical yearbook (fishing). No data are available on hunting.

As concerns unused domestic extraction, coefficients for energetic resources (oil and natural gas) were calculated on the basis of drilling related waste provided in the annual reports of the Italian energy company ENI. Waste statistics reported by the Italian companies combined with production data from PRODCOM survey (for NACE 13 and 14) were used to estimate coefficients for the calculation of a unused non energetic materials. Estimates of unused material resulting from biomass (standardized to 15% water content, except for fishing residues) were made using either coefficients found in the scientific and technical literature (agriculture) or data on residues provided by ISTAT's survey (wood removal) or other coefficients from literature (e.g. fishing). As concerns excavated soil (excluding dredging), estimates are on based ISTAT's survey plus data from a research centre on the construction market (building); data from the national railway companies and the national companies for roads maintenance (excluding motorways), as well as on ISPRA's waste statistics (proportion of material reused for construction purposes).

Indirect flows associated to international trade are calculated thanks to coefficients provided by the Wuppertal Institute.

The material input time series of the Italian economy is updated on a yearly basis.

As far the PIOT is concerned, ISTAT realized for the year 1997 an aggregated prototype describing the flows between natural environment, production, consumption and man-made stocks of natural resources, ecosystem inputs, products and residuals. This prototype includes supply and use tables as well as highly aggregated PIOTs by kind of material, that are coherent with the SEEA and the most recent OECD guidelines (OECD MFA Manual Volume II). Publication of these tables is forthcoming.

4.6 Switzerland

The Federal Statistical Office (FSO) is the lead institution for economy-wide material flow analysis (EW-MFA) in Switzerland. The Federal Office for the Environment (FOEN) is mainly concerned with the evaluation of certain material flows. Additionally, MFA-related work is carried out by local waste management agencies (e.g. in the Cantons of Zurich, Geneva, St. Gallen and Thurgau) and research institutes such as the Swiss Federal Institute of Technology (Zurich, Lausanne) and the Swiss Federal Laboratories for Materials Testing and Research.

MFA Activities in Switzerland

Switzerland has mainly conducted material flow related work in the fields of substance flow analysis (SFA) and MFA applied to waste management at local and research level. Economy-wide material flow accounting is a more recent activity. A feasibility study (BFS 2005) was carried out by the government in 2003-2004. The FSO has published EW-MFA indicators, including the TMR, on an annual basis since 2003.

The environmental accounts developed by the FSO are based on SEEA 2003 and include economic (SERIEE), physical (EW-MFA) and integrated accounts (NAMEA). The feasibility study on EW-MFA was based on EUROSTAT (2001) methodology. It demonstrated the feasibility of such accounts in Switzerland and highlighted certain methodological problems. This first study allowed the estimation of direct inputs (domestic extraction and imports) and exports with a time series from 1981 to 2001. Since 2004, the FSO has consolidated the data and extended the time series up to 2007. The accounts were also extended by evaluating unused domestic extraction and hidden flows linked to imports. Finally, in 2008, domestic processed output (DPO) was evaluated, thus also allowing the indirect estimation of the net addition to stock (NAS) through the estimation of the balancing items. A complete EW-MFA is available for the time series 1990-2007. EW-MFA are compiled in accordance with EUROSTAT methodology (2001, 2007) using the nomenclature of the Eurostat standard tables. As of autumn 2009, the accounts will comply with the residence principle. The complete accounts are updated annually (last update: April 2009).

MFA also plays an important role in connection with sustainable development in Switzerland. The Swiss government's Sustainable Development Strategy (SWISS FEDERAL COUNCIL 2008) identifies Integrated Product Policy (IPP) as a measure to achieve certain goals of sustainable development. Sustainable material management is part of the IPP and strategies are to be proposed to reduce consumption and environmental impact while maintaining or improving product quality. The material intensity of a national economy (TMR/PTB) is one of the 55 indicators for sustainable development defined in the Sustainable Development Strategy. The Swiss indicator system for monitoring sustainable development (MONET), which includes TMR and material intensity, is a joint activity of the Federal Statistical Office (FSO), the Federal Office for the Environment (FOEN) and the Federal Office for Spatial Development (ARE).

The FSO offers access to statistical information (mainly in German and French, but also in English) including detailed EW-MFA datasets and data on all major EW-MFA indicators through its website at www.environment-stat.admin.ch.

Used Indicators, Results and Findings

The main indicators derived from material flow accounts include TMR, DMC, DMI, DE (used), PTB, material productivity, DPO and NAS. The observation of the TMR, imports and hidden flows linked to imports is particularly important for a country such as Switzerland whose economy is essentially based on the tertiary sector.

To meet the demands of Switzerland's economy and its private households, some 335 million tonnes of materials (i.e. more than 44 tonnes per person) were extracted, consumed or displaced in Switzerland or abroad in 2007. The total material requirement (TMR), comprising all direct and indirect material flows associated with the country's economic activities, thus rose by 10.4% between 1990 and 2007.

While material productivity (GDP/TMR) in Switzerland rose in the early 1990s, it has since fluctuated without showing any clear trend. Thus, to date, neither has there been a decoupling between economic growth and resource consumption, nor has the economy been 'dematerialised' (dematerialisation occurs when TMR falls while GDP rises).

Direct flows (i.e. the materials directly used by the economy) consist of materials extracted in Switzerland and imported raw materials and finished products. In 2007, direct flows accounted for only 33% of TMR, or 14.4 tonnes per person. The other 67% is attributable to indirect flows, which cover unused domestic extraction and hidden flows associated with imports. The large proportion accounted for by indirect flows underlines the significance of this frequently overlooked category of material flows.

Between 1990 and 2007, the domestic part of TMR (i.e. materials extracted in Switzerland) declined from 38% to 32%. Only biomass and construction minerals are sourced domestically, as Switzerland's landmass contains no recoverable natural resources such as fossil products or metals. The extraction of construction minerals is closely linked to the level of activity in the construction sector. The production of biomass, which is influenced by climatic conditions or extreme weather events, is on a downward trend.

Over the same period (1990-2007), the foreign component of TMR, comprising imports and the associated hidden flows, rose by 9%. Imports of materials increased continuously from 2000, reaching almost 50 million tonnes in 2007. The composition of imports also changed. From 1990, the volume of raw materials fell by 5%, while finished products rose by 60% and accounted for around 37% of total imports in 2007. Switzerland is therefore increasingly dependent on other countries. In addition, as a result of Swiss consumption patterns and the tertiarisation of the economy, environmental pressures are increasingly being shifted abroad (BFS 2007, 2008).

MFA and Environmental Aspects

The FOEN evaluates different material and commodity flows in Switzerland. Current projects aim at demonstrating the consumption of certain materials including their substance and hidden flows, as well as their specific environmental pressures. The results will be used to develop a basis for decision-making and to draw up a strategy on sustainable material management.

A wood resource policy has already been established (FOEN 2008). It is a strategy including an action plan (with financial incentives) to support the consistent but sustainable use of wood from domestic forests and the resource-efficient use of wood as a raw material with an emphasis on its ecologically and economically sound use. Similarly, the strategy on the production, processing and use of biomass in

Switzerland (BFE et al. 2009) defines the sustainability principles for the handling of biomass.

Life cycle assessment, ecological footprint and other methods are being used to evaluate material flows. An evaluation of plastics, electric and electronic equipment has been completed. An analysis is currently under way on material flows in connection with the use of the internet. Based on available data, the material and energy consumption as well as the environmental impacts of internet services in Switzerland are being estimated and demonstrated.

Outlook

In addition to keeping up to date with Eurostat and OECD developments, the FSO plans to engage in the following activities:

- calculation of the net addition to stock with a direct method;
- calculation of the breakdown of input flows by economic activity (NAMEA approach) and/or development of Input-Output tables;
- improvement of estimation quality of hidden flows linked to imports;
- evaluation of the feasibility of estimating hidden flows linked to exports;
- evaluation of the feasibility of estimating raw materials equivalent indicators;
- facilitating the wide-spread use of EW-MFA indicators.

4.7 United Kingdom

In the United Kingdom, the Office for National Statistics (ONS) is responsible for updating and maintaining the Material Flow Account for the United Kingdom.

The UK Material Flow Accounts were originally compiled by the Wuppertal Institute on behalf of the then Department for Environment, Transport and Regions now the Department for Environment, Food and Rural Affairs (Defra). The initial accounts were published in 2002 in the report entitled *Total Material Resource Flows of the United Kingdom* (obtainable from Defra).

This, and subsequent MFA work followed the standards set out by Eurostat's methodological guide (EUROSTAT 2001). This scope of the MFA included four broad categories of raw materials, semi-manufactured products and finished products from:

- Fossil fuels
- Metallic Minerals
- Non-metallic minerals
- Biomass.

The accounts are now compiled and published by the ONS annually and provide a limited dataset focusing on the input and consumption side of the accounts from 1970 onwards. The key indicators currently published are:

- Direct Material Input (domestic extraction + imports)
- Domestic Material Consumption (domestic extraction + imports – exports)
- Total Material Requirement (direct material input + indirect and hidden flows).

The outputs from this work are used to inform national policy and actions to facilitate progression towards sustainable development.

Environmental accounts data, including MFA, are publicly available and can be downloaded from: http://www.statistics.gov.uk/statbase/Product.asp?vlnk=3698.

5 COMPLEMENTARY APPROACHES

The European Commission has, as part of implementing the Thematic Strategy on the Sustainable Use of Natural Resources, commissioned the development of resource productivity and resource impact indicators. A corresponding study (BEST et al. 2008) led to the recommendation to apply following 4 approaches:

- Ecological Footprint
- Environmentally weighted material consumption (EMC)
- Human Appropriation of Net Primary Production (HANPP).
- Land and Ecosystem Accounts (LEAC)

Table 3 summarises and compares these approaches. It can be concluded that MFA forms the basis for calculating the Ecological Footprint, the EMC and the HANPP. For an analysis of the environmental impact of non-renewable materials the EMC seems to be the most relevant indicator.

Table 3: Summary of key aspects to the resource use indicators ecological footprint, Environmentally weighted material consumption (EMC), Land and Ecosystem Accounts (LEAC) and Human Appropriation of Net Primary Production (HANPP) (BEST et al. 2008)

	Ecological Footprint	EMC	HANPP	LEAC
Main issues addressed	How much of the regenerative capacity of the planet is occupied by a given human activity or population? In which countries biocapacity is located?	What is the global environmental impact potential of materials consumed in a national economy and where does it occur in the production and recycling of materials?	How intensely are ecosystems being used by human beings?	For which economic activities are different land areas being used?
Covered impact categories*	Resource consumption (Climate change) (Land use) (Impact on ecosystems and biodiversity)	Climate change Human health (Land use) Stratospheric ozone depletion Eco-toxicity Photo-oxidant formation Acidification Eutrophication Ionizing radiation	(Impact on ecosystems and biodiversity) Land use	(Impact on ecosystems and biodiversity) Land use
Complementary property in basket	Provides clear benchmark for assessments of carrying capacity and overshoot. Allows assessing the impacts of natural resource use on the regenerative capacity of ecosystems.	Covers impacts independent from absorption capacities, such as human health and eco-toxic impacts of certain materials or issues of ozone depletion, eutrophication, acidification, etc.	Relates material flows (biomass extraction) to pressures on ecosystems. Monitors the intensity of ecosystem and land use and establishes links to natural capital deterioration (e.g. soil erosion) and pressures on biodiversity.	Links land cover change to socio-economic (sectoral) aspects of land use. Assesses spatially explicit consequences of resource use for land cover change.
Data requirements	Data on material flows, land use and CO_2 emissions.	Material flow data / production and trade statistics.	Agricultural and forestry statistics and inventories, land use statistics, remotely-	Remote-sensed (satellite) data. Data on net primary

	Ecological Footprint	EMC	HANPP	LEAC
	Conversion factors for transformation of resource and waste flows into necessary biocapacity to sustain flows (measured in global hectares).	Data on life cycle wide emission inventories and environmental impacts of different materials.	sensed (satellite) data.	production. Demographic data and spatially distributed economic data.
Strengths	Integrates all resource use in terms of demand on regenerative capacity. Allows relating human demand to supply by nature and determining clear target. Considers trade flows (including embodied energy). Based on a clear research question.	Comprehensive measure based on biotic and abiotic resource accounts. Covers a large number of LCA impact categories. Includes direct trade flows and life-cycle wide impacts associated with these flows.	Provides an illustrative and spatially explicit indicator on human pressures on ecosystems. Can serve as early warning indicator for land degradation and pressure on biodiversity.	Provide a SEEA-compatible account for impacts of resource use on land cover and land use and changes over time. Bridges with monetary valuation of ecosystem services and maintenance costs of ecosystems.
Limitations and weaknesses	The Ecological Footprint cannot cover impacts for which no regenerative capacity exists (e.g. pollution in terms of waste generation, toxicity, eutrophication, etc..) It shows pressures that could lead to degradation of natural capital (e.g. reduced quality of land or reduced biodiversity), but does not predict this degradation.	Not an accounting approach, but an aggregate of separate assessments. Subjective weighting necessary, to take into account "relevance" of the different LCA impact categories. No endogenous definition of benchmarks / sustainable levels.	No endogenous definition of benchmarks/sustainable levels. No consideration of trade and trade-related demand on biosphere.	Sectoral information (in particular industry and service sector) very aggregated. No endogenous definition of benchmarks / sustainable levels. No consideration of trade.

*Note: Brackets indicate that impact category is only partly covered.

Similar approaches have been developed in other countries. The Swiss ecological scarcity method, for example, takes a closer look – among other things – at resources consumption during the whole life cycle of products and services. It attributes a certain number of eco-points to pollutant emissions or resource consumption and thus allows for impact assessment within a life cycle assessment (LCA) framework.

The following sub-chapters give a short introduction to the 4 resource use indicator approaches and the Swiss ecological scarcity method.

5.1 Ecological Footprint

The Ecological Footprint specifies how much area is consumed to cover the needs of a country, a society, a sector, a company a household or a person. When calculating this area raw material and land use in foreign countries is taken into account, as well as the fact that also waste and emissions require biologically productive areas to be absorbed by nature. Forest areas which are necessary to absorb the carbon dioxide, which is emitted to the atmosphere through burning of fossil energy carriers, and transform it into biomass again represent a major part of this so-called sequestration area. By this concept it is also possible to assess the available biologically productive land and water area in a country or on the earth as a whole. By comparing the Ecological Footprint with the overall available ecological capacity, one is able to assess whether there is still a margin for further growth or mankind already overuses the natural systems (SERI 2006).

For Austrian consumers/citizens an ecological footprint calculator is available on the internet (www.mein-fussabdruck.at). With this tool everybody can calculate her/his individual ecological footprint.

Ecological Footprint and Material Flow Analysis

The calculation of the Ecological Footprint is to a large extent carried out with data on the consumption of natural resources which are collected by means of Material Flow Accounting and Analysis (MFA). A solid and standardized database is therefore the basis both for the calculation of the Ecological Footprint and for the material consumption of cities or countries (SERI 2006).

Different institutes in the area of the Footprint or MFA have recently published the claim for a uniform and consistent database together with Friends of The Earth Europe in a **common declaration** under the leadership of SERI (SERI 2006).

5.2 Environmentally weighted material consumption (EMC)

The environmentally weighted material consumption (EMC) is an indicator for the environmental impact of resource use. The idea behind the EMC is simple: multiply the material flows with a factor representing their environmental impacts.

In a European project by Leiden University, Wuppertal Institute and CE Solutions the EMC for 25 EU Member Countries for the years 1990 to 2000 and for then 3 Accession Countries for the period 1992 to 2000 were calculated the following way:

1. Raw materials (e.g. sand) were allocated to 31 finished material types (e.g. concrete)
2. For each of these 31 finished material types following 13 specialised environmental impact indicators were calculated per kg material based on life-cycle analysis data from Western Europe 1995:
    a. Global warming potential
    b. Stratospheric ozone depletion potential
    c. Acidification potential
    d. Eutrophication potential
    e. Photochemical ozone formation potential
    f. Abiotic resource depletion
    g. Human toxicity

h. Aquatic ecotoxicity

i. Terrestrial ecotoxicity

j. Marine ecotoxicity

k. Final solid waste generation

l. Radiation

m. Land competition.

3. Each specialised environmental impact indicator is normalised by dividing it through the world impact (e.g. the global warming potential of concrete is divided by the world global warming potential).

4. For each of the 31 finished material types a total environmental impact indicator per kg material by summing up the 13 normalised specialised environmental impact indicators (without weighing them).

5. For each of the 31 finished material types the total environmental impact indicator was multiplied by the DMC of each material type for a given country and a given year to give the EMC of each finished material type for a given country and a given year.

6. Summing up the EMCs of the 31 material types gives the EMC of a given country in a given year (VAN DER VOET ET AL. 2005).

A time series of the derived indicator EMC/GDP may be used to show if an economy achieves a decoupling of resource use environmental impact from economic growth.

5.3 Human Appropriation of Net Primary Production (HANPP)

Net primary production (NPP) is the net amount of organic matter produced by green plants through photosynthesis in a defined period of time (usually one year). NPP is an indicator for the amount of energy captured through photosynthesis and consequently available for all heterotrophic food webs (herbivory, detritivory or – indirectly – carnivory) or for accumulation in the form of living or dead biomass in ecosystems ("carbon sink"). NPP can be measured as yearly flow of dry matter biomass (in t/a), as carbon flow (in t Carbon/a) or as energy flow (in J/a). 1 kg of dry matter biomass contains approximately 0.5 kg carbon and typically has a gross calorific value of approximately 18.5 MJ, depending on its chemical composition.

HANPP is a measure of the intensity with which humans interfere with these basic energetic processes in ecosystems (VITOUSEK ET AL. 1986, WRIGHT 1990, HABERL ET AL. 2007). It is a measure of the intensity of land use and is also indicative for human pressures on biodiversity and ecosystem services.

In the absence of human intervention, NPP primarily depends on soil quality, climate (temperature and precipitation), and the CO_2 content of the atmosphere. Through land use, humans alter the productivity of the vegetation, thereby creating a situation in which the NPP of the vegetation actually present at any defined point in time (NPP_{act}) differs from the productivity of the vegetation that would prevail in the absence of human intervention (NPP_0). This difference is denoted as ΔNPP_{LC} (change in NPP resulting from land conversion). In addition, humans change the amount of NPP available for natural ecosystem processes by harvesting biomass (NPP_h). HANPP is defined as the sum of ΔNPP_{LC} and NPP_h (HABERL ET AL. 2007). HANPP can be measured in the same units as NPP and it can also be expressed as a percentage of the NPP of potential vegetation (NPP_0).

Using appropriate land-use maps (e.g. ERB ET AL. 2007), HANPP can be calculated and mapped for any area that might be of interest. A global HANPP map is available for the entire terrestrial biosphere (except Greenland and Antarctica) with a spatial resolution of 5min (ca. 10 x 10 km at the equator) for the year 2000 (HABERL ET AL. 2007). On a national level, current HANPP data refer to a nation's territory but not to the consumption of resources of that nation's population. Using appropriate biomass flow data (e.g., KRAUSMANN ET AL. 2008), it would also be possible to establish accounts of the amount of HANPP "embodied" in the biomass consumed within a national economy; that is, the HANPP that was caused during the provision of the biomass-based products used up in that economy. Methods to establish such accounts are currently under development at the Institute of Social Ecology at Klagenfurt University.

5.4 Land and Ecosystem Accounts (LEAC)

The European Environment Agency has started the implementation of a programme of land use and ecosystem accounts, following the System of Environmental and Economic Accounts guidelines of the United Nations. The purpose is to integrate information across the various ecosystem components and to support further assessments and modelling of these components and their interactions with economic and social developments.

The accounts are based on explicit spatial patterns provided by comprehensive land cover accounts that can be scaled up and down using a 1 km^2 grid to any type of administrative region or ecosystem zone (e.g., river basin catchments, coastal zones or bio-geographic areas). Land cover accounts have been produced for 24 countries in Europe and first results published in the European Environment State and Outlook2005 report of the EEA (EEA 2005b, WEBER 2007).

5.5 Ecological scarcity method (for impact assessment in LCA)

The Swiss ecological scarcity method is a method for impact assessment in LCA which rates environmental impacts using an "eco-point" metric. Each environmental impact is weighted with an eco-factor, which reflects an environmental law or a corresponding political target. High levels of emissions or resource consumption in comparison to an environment protection target result in greater eco-factors. Each environmental impact is expressed in eco-points: the greater the number of eco-points, the greater the environmental impact. The fact that every individual impact is expressed by means of a common unit allows for aggregation resulting in a statement of the overall environmental impact of any given product or service.

The determination of the eco-factors takes three elements into account: characterization, normalization and weighting.

Characterization expresses the relative harmfulness of a pollutant emission or a resource extraction compared to a reference substance. Different emissions can contribute to the same type of impact but differ in their impact intensity. For instance, carbon dioxide and methane both drive climate change but the impact of methane is 23 times that of carbon dioxide. The quantities are usually expressed in equivalents of the reference substance.

Normalization compares the contribution of a unit of pollutant or resource use to the total pressure in an area. For instance, a contribution of 10% of the annual release of a certain substance is significant and results in a greater eco-factor compared to the release of only 0.1% of the annual load. Normalization using the current load has the effect that emissions or resource extractions that are only problematic in large quantities carry less weight.

Weighting reflects the circumstance that a certain emission level need not necessarily have a harmful effect. Problems only arise after a critical threshold is exceeded. This threshold is legally or politically determined. The distance between the current situation and the target is defined as ecological scarcity. The greater the distance to target, the more eco-points are attributed to a substance (FRISCHKNECHT et al. 2009).

The ecological scarcity method considers resource consumption when assessing products and services within an LCA framework. MFA provides an insight into the extent of resource consumption and in connection with LCA can allow for conclusions on sustainable consumption and sustainable material management.

6 CONCLUSIONS AND RECOMMENDATIONS

More and more of the resources we use are attached to imported products. Consequently, a growing share of the impact we cause by consuming these resource occur in other countries.

Therefore, resource policy and resource indicators which exclude the indirect flows and environmental impacts caused in other countries neglect an important part of our responsibilities and our possible contribution to a world wide optimum of resource use efficiency.

Therefore it is necessary to complement indicators containing only direct material input by indicators which also take into account the indirect effects of meeting our final demand. Several approaches are currently under development such as the product-based approach with the derived indicator TMR (total material requirement) or Input-Output-based approaches which result in indicators such as DMC_{RME} and RMC. Methodological standards for calculating indirect flows for a broad set of countries and in time-series are still to be developed.

The Interest Group Resources of the Environmental Protection Agencies Network recommends

- the development and introduction of standards for calculating the indirect flows and derived indicators such as TMR and DMC_{RME} or equivalent indicators
- the regular determination of TMR and DMC_{RME} or equivalent indicators for each European Environment Agency member country ideally based on statistically reported data
- the use of the TMR and DMC_{RME} or equivalent indicators as basis for resource policy making.

The basis for material flow analysis and especially economy wide material flow accounts are monetary and physical trade balances. Eurostat, however, has noted increasing problems with the quality and coverage of the trade statistics – cut-offs for inclusion are increasing, reducing what is included. Consequently the correspondence between the monetary and physical trade statistics is becoming more and more problematic[4].

Therefore the Interest Group Resources recommends

- to take efforts to keep trade statistics on a high level of quality and coverage and
- to support the reporting regulation covering the input side of economy wide material flow accounts as proposed by Eurostat.

Furthermore, the Environmental Protection Agencies should:

- support the establishment of regular material flow accounting in their respective countries taking into account indirect flows;

[4] Personal communication Eurostat 10.09.2009

- apply MFA (Material Flow Analysis)-indicators in their analyses for environmental and economic policy decision support.

These recommendations can be seen as complement to the recommendations of the OECD Environment Policy Committee on the analysis of the material flows and their environmental impacts by OECD member countries.

Table 4: Recommendations of the OECD Environment Policy Committee on the analysis of the material flows and their environmental impacts by OECD member countries (OECD COUNCIL ON RESOURCE PRODUCTIVITY 2008).

Promote resource productivity by strengthening their capacity for analysing material flows and the associated environmental impacts, and work to improve measurement systems for material flows and resource productivity, drawing on the expertise of all relevant ministries and departments of government, research and other non-governmental organisations, on OECD guidance and experience on measurement and analysis of material flows and resource productivity and on other international work; and to this effect: 1. Improve the scientific knowledge concerning the environmental impacts and costs of resource use throughout the entire life cycle of materials and the products that embody them, from natural resource extraction and manufacturing to end of life management (as wastes, reusables and recyclables), including from resources that have been imported. 2. Upgrade the extent and quality of data on material flows within and among countries and the associated environmental impacts, giving particular attention to the availability and international comparability of data on physical trade flows, including flows of recyclable materials and waste, and selected material flows that are of economic and environmental importance. 3. Work to improve and use soundly based, relevant and internationally compatible material flow accounts that track natural resource stocks and flows and link them to critical environmental cycles. 4. Further develop and promote the use of indicators for the assessment of the efficiency of material resource use, having carefully considered the uses and purposes, practical arrangements, costs, benefits and statistical basis for such indicators, including: • indicators to measure resource productivity and decoupling of resource use from economic growth, at relevant macro, sectoral and/or micro levels, considering both: overview indicators for monitoring natural resource use, resource productivity and the associated environmental impacts; and specific and disaggregated indicators for monitoring resource use, resource productivity, 3R (Reduce, Reuse, and Recycle) related flows and the associated environmental impacts concerning particular resources, materials or activities; • indicators to inform about the availability, quality and deterioration of natural resource stocks, in particular renewable resource stocks; • indicators to track the flows and environmental impacts of materials, taking account of their entire life cycle from natural resource extraction and manufacturing to end of life management. 5. Co-operate with non-Member Economies to strengthen their capacity for analysis of material flows and the associated environmental impacts. 6. Share OECD guidance and experience on measurement and analysis of material flows and resource productivity with all relevant ministries and departments of government, research and other nongovernmental organisations, and members of the private sector.

7 ABBREVIATIONS

ARE	Federal Office for Spatial Development of Switzerland
BFE	Swiss Federal Office of Energy
BGR	German Federal Institute for Geosciences and Natural Resources
CDW	Construction & Demolition Waste
CN	Combined Nomenclature
DE	Domestic Extraction
Defra	Department for Environment, Food and Rural Affairs
DESTATIS	German Federal Statistical Office
DMC	Domestic Material Consumption
DMC_{RME}	Domestic Material Consumption expressed in Raw Material Equivalents
DMI	Direct Material Input
DMO	Direct Material Output
DPO	Domestic Processed Output
DRD	Domestic Resource Dependency
EEA	European Environment Agency
eIOA	environmental Input-Output Analysis
eIO-model	environmental Input Output model
EPA	Environmental Protection Agency
EWC	European Waste Catalogue
EW-MFA	Economy-Wide Material Flow Accounts
FOEN	Federal Office for the Environment of Switzerland
FSO	Federal Statistical Office of Switzerland
GDP	Gross Domestic Product
GNP	Gross National Product
GWS	Insitute for Economic Structures Research, Osnabrück, Germany
HANPP	Human Appropriation of Net Primary Production
IO	Input-Output
IPP	Integrated Product Policy
ISPRA	Instituto Superiore per la Protezione e la Ricerca Ambientale
ISTAT	Italian Statistical Office
LCA	Life Cycle Analysis
LEAC	Land and Ecosystem Accounts

MEFIS	Material and Energy Flow Information System
MF	Material Flow(s)
MFA	Material Flow Analysis, Material Flow Accounting
MIOTs	Monetary Input-Output Tables
MIPS	Material Input Per Service
MONET	Swiss indicator system for monitoring sustainable development
MOSUS	Modelling Opportunities and limits for restructuring Europe towards SUStainability
NACE	Nomenclature générale des activités économiques (Classification of Economic Activities in the European Community)
NAMEA	National Accounting Matrix including Environmental Accounts
NAS	Net Additions to Stock
NPP	Net Primary Production
NRA	Natural Resource Accounts
NSO	National Statistical Office
OECD	Organisation for Economic Co-operation and Development
ONS	Office for National Statistics United Kingdom
PIOT	Physical-Input-Output Tables
PRODCOM	Production Communautaire - EU-system of production statistics in mining and production of goods
PTB	Physical Trade Balance
PTBIF	Physical Trade Balance including Indirect Flows
R&D	Research and Development
RMC	Raw Material Consumption
RME	Raw Material Equivalents
RMTB	Raw Materials Trade Balance
SEEA	System of Integrated Environmental and Economic Accounting
SERI	Sustainable Europe Research Institute
SERIEE	European System for the Collection of Economic Information on the Environment
SFA	Substance Flow Analysis
SNA	System of National Accounts
TDO	Total Domestic Output
TMC	Total Material Consumption
TMI	Total Material Input
TMO	Total Material Output
TMR	Total Material Requirement

UBA	German Federal Environment Agency
WRI	World Resources Institute, Washington D.C., http://www.wri.org/

8 LITERATURE

BEHRENDT, S.; SCHARP, M.; ERDMANN, L.; KAHLENBORN, W.; FEIL, M.; DEREJE, C.; BLEISCHWITZ, R. & DELZEIT, T. (2007): Rare metals: Measures and concepts for the solution of the problem of conflict-aggravating raw material extraction – the example of Coltan, Environmental Research of the Federal Ministry of the Environment Nature Conservation and Nuclear Safety, Research Report 363 01 124, Federal Environment Agency, http://www.umweltdaten.de/publikationen/fpdf-l/3251.pdf.

BEST, A.; BLOBEL, D.; CAVALIERI, S.; GILJUM, ST.; HAMMER, M.; LUTTER, ST.; SIMMONS, C. LEWIS K. & MAGUIRE, C. (2008): Potential of the Ecological Footprint for monitoring environmental impacts from natural resource use. Ecologic, SERI, Best Foot Forward, Report to the European Commission, DG Environment. Berlin.

BFE - Bundesamt für Energie, BLW - Bundesamt für Landwirtschaft, ARE - Bundesamt für Raumentwicklung & BAFU Bundesamt für Umwelt (2009): Biomassestrategie Schweiz – Strategie für die Produktion, Verarbeitung und Nutzung von Biomasse in der Schweiz. http://www.bafu.admin.ch/dokumentation/medieninformation/00962/index.html?lang=de&msg-id=26306.

BFS - Bundesamt für Statistik (2005): Materialflussrechnung für die Schweiz: Machbarkeitsstudie. Statistik der Schweiz. BFS, Neuchâtel. http://www.bfs.admin.ch/bfs/portal/de/index/themen/02/22/publ.html?publicationID=1811.

BFS - Bundesamt für Statistik (2007): Materialflüsse in der Schweiz: Ressourcenverbrauch der Schweizer Wirtschaft zwischen 1990 und 2005. Statistik der Schweiz. BFS, Neuchâtel. http://www.bfs.admin.ch/bfs/portal/de/index/news/publikationen.html?publicationID=2672.

BFS - Bundesamt für Statistik (2008): Materialaufwand der Schweiz: Umweltstatistik Schweiz Nr. 14. Statistik der Schweiz. BFS, Neuchâtel. http://www.bfs.admin.ch/bfs/portal/de/index/themen/02/22/publ.html?publicationID=3414.

BRINGEZU, S. (2003): Aspekte der Analyse des gesellschaftlichen Stoffwechsels - Systemgrenzen und ökologischer Rucksack. CD: Klausurtagung des wissenschaftlichen Rates für Abfallwirtschaft und Altlastensanierung, Puchberg am Schneeberg, 23.-24.10.2003.

BRINGEZU, S. (2006): Materializing Policies for Sustainable Use and Economy-wide Management of Resources: Biophysical Perspectives. Socio-Economic Options and a Dual Approach for the European Union, No. 160, June, Wuppertal Institute for Climate, Environment and Energy, http://www.wupperinst.org/uploads/tx_wibeitrag/WP160.pdf.

BRINGEZU, S.; RAMESOHL, ST.; ARNOLD, K.; FISCHEDICK, M.; GEIBLER, J.V.; LIEDTKE, CH. & SCHÜTZ, H. (2007): What we know and what we should know: Towards a sustainable biomass strategy. Discussion paper, No. 163, June, Wuppertal Institute for Climate, Environment and Energy, http://www.wupperinst.org/uploads/tx_wibeitrag/WP163.pdf.

BRUNNER, P.H. & RECHBERGER, H. (2004): Practical Handbook of Material Flow Analysis. Lewis Publishers, Boca Raton, 2004.

CURRY, R., MAGUIRE, C., SIMMONS, C., LEWIS, K., MOLES, R., O'REGAN, B. & WALSH, C. (2008): Island Limits - A Resource Flow Analysis and Ecological Footprint of Ireland. Environmental Protection Agency, Johnstown Castle Estate, CountyWexford, Ireland. Synthesis Report on http://www.epa.ie/downloads/pubs/research/econ/STRIVE%201web-cover.pdf.

EEA – European Environment Agency (2005a): Sustainable use and management of natural resources. EEA Report 9/2005, Copenhagen.

EEA – European Environment Agency (2005b): The European Environment State and Outlook 2005. Copenhagen.

ERB, K.-H.; GAUBE, V.; KRAUSMANN, F.; PLUTZAR, C.; BONDEAU, A. & HABERL, H. (2007): A comprehensive global 5min resolution land-use dataset for the year 2000 consistent with national census data. Journal of Land Use Science 2(3), 191-224.

EUROPEAN COMMISSION (2005a): Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions - Thematic Strategy on the sustainable use of natural resources. COM (2005) 670, 21.12.2005.

EUROPEAN COMMISSION (2005b): Annexes to the Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions - Thematic Strategy on the sustainable use of natural resources COM(2005) 670 final. SEC (2005)1684, 21.12.2005.

EUROSTAT (2001): Economy-wide Material Flow Accounts and Derived Indicators. A methodological guide. Luxembourg: Eurostat, European Commission, Office for Official Publications of the European Communities.

EUROSTAT (2007): Economy-wide Material Flow Accounting. A Compilation Guide. Luxembourg: European Statistical Office.

FEDERAL MINISTRY FOR THE ENVIRONMENT (2002) Nature Conservation and Nuclear Safety: Perspectives for Germany – Our Strategy for Sustainable Development 2002. www.bundesregierung.de/webs/breg/en/homepage/home.html.

FOEN - Federal Office for the Environment (2008): Wood Resource Policy: Strategy, Objectives and Action Plan for the Resource Wood. FOEN, Bern. http://www.bafu.admin.ch/wald/01234/06811/index.html?lang=en.

FRISCHKNECHT, R.; STEINER, R. & JUNGBLUTH, N. (2009): The Ecological Scarcity Method – Eco-Factors 2006. A method for impact assessment in LCA. Environmental studies no. 0906. Federal Office for the Environment, Bern: 188 pp.

GERMAN FEDERAL ENVIRONMENT AGENCY, GERMAN FEDERAL STATISTICAL OFFICE, FEDERAL INSTITUTE FOR GEOSCIENCES AND NATURAL RESOURCES (2007): "Environmental Data for Germany, Practicing Sustainability – Protecting Natural Resources and the Environment". http://www.umweltbundesamt.de/ressourcen-e/index.htm.

GILJUM, S. & HUBACEK, K. (2008): Conceptual foundations and applications of physical input-output tables. In: Suh, S. (ed.): Handbook of input-output economics for industrial ecology. Springer, Dordrecht, The Netherlands.

GILJUM, ST.; LUTZ, CH. & JUNGNITZ, A. (2008a): The Gloabl Resource Accounting Model (GRAM) - A Methodological Concept Paper. SERI Studies Nr. 8, Vienna.

GILJUM, ST.; LUTZ, CH.; JUNGNITZ, A.; BRUCKNER, M. & HINTERBERGER, F. (2008b): Global dimensions of European natural resource use - Results from the Global Resource Accounting Model (GRAM). Proc. OECD-UNEP Conference on Resource Efficiency, 23-25 April 2008, Paris.

HABERL, H.; ERB, K.-H.; KRAUSMANN, F.; GAUBE, V.; BONDEAU, A.; PLUTZAR, C.; GINGRICH, S.; LUCHT, W. & FISCHER-KOWALSKI, M. (2007): Quantifying and mapping the human appropriation of net primary production in earth's terrestrial ecosystems. Proceedings of the National Academy of Sciences of the USA 104, 12942-12947

ISTAT (2000). A material flow account for Italy, 1988.

ISTAT (2003). 1980-1998 Material-Input-Based Indicators Time Series and 1997 Material Balance of the Italian Economy.

ISTAT (2004). Update of the Economy-wide material flow indicators time series for Italy and Italian Physical Input Output Table feasibility study.

KRAUSMANN, F.; ERB, K.-H.; GINGRICH, S.; LAUK, C. & HABERL, H. (2008): Global patterns of socioeconomic biomass flows in the year 2000: A comprehensive assessment of supply, consumption and constraints. Ecol. Econ. 65, 471-487.

LEONTIEF, W.; KOO, J.; NASAR, S. & SOHN, I. (1982): The production and consumption of non-fuel minerals to the year 2030 analyzed within an input-output framework of the U.S. and world economy. NSF/CPE-82002. National Science Foundation, Washington, DC.

MAGUIRE, C. & CURRY, R. (2007): Measuring Ireland's Sustainability. The integration of environmental data in macroeconomic models. Comhar –Sustainable Development Council Working Paper, Dublin.

MILLER, R. E., & P. BLAIR (1985): Input-Output Analysis: Foundations and Extensions, Prentice Hall, Inc.

MOLL, S.; BRINGEZU, S. & SCHÜTZ, H. (2005): Resource Use in European Countries. Wuppertal Report No.1, December, Wuppertal Institute for Climate, Environment and Energy. http://www.wupperinst.org/uploads/tx_wibeitrag/wr1.pdf.

OECD (2008a): Measuring Material Flows and Resource Productivity. Synthesis Report. Paris. http://www.oecd.org/dataoecd/55/12/40464014.pdf

OECD (2008b): Measuring Material Flows and Resource Productivity. Volume 1 - The OECD Guide. Paris. http://www.oecd.org/dataoecd/46/48/40485853.pdf

OECD (2008c): Measuring Material Flows and Resource Productivity. Volume 2 - The Accounting Framework. Paris. http://www.oecd.org/dataoecd/46/51/40486044.pdf

OECD (2008d): Measuring Material Flows and Resource Productivity. Volume 3 - Inventory of country activities. Paris. http://www.oecd.org/dataoecd/47/28/40486068.pdf

OECD COUNCIL ON RESOURCE PRODUCTIVITY (2008): Recommendation of the Council on Resource Productivity C(2008)40. Meeting of the Environment Policy Committee (EPOC) at Ministerial Level "Environment and Gloabl Competitiveness" 28-29 April 2008, adopted by the OECD Council on 28 March 2008.

OENORM S 2096-1. 2005. Material flow analysis – Part 1: Application in waste management - Concepts. Österreichisches Normungsinstitut. Wien.

OENORM S 2096-2. 2005. Material flow analysis – Part 2: Application in waste management - Methodology. Österreichisches Normungsinstitut, Wien.

O'LEARY, E. & CUNNINGHAM, D. (2006): Material Flow Accounts (MFAs) - Demonstration for Ireland Environmental Protection Agency, Johnstown Castle Estate, CountyWexford, Ireland. Synthesis Report on http://www.epa.ie/downloads/pubs/research/waste/EPA_material_flow_accounts_ERTDI45_synthesis.pdf.

PETROVIC, B. (2007): Materialflussrechnung, Inputreihe 1960 bis 2005 Statistik Austria, Wien.

RADERMACHER, W. (1998): Material Flow Accounting – Input into the Decision Process for Sustainable Development. In: Wuppertal Special 6, Analysis for Action: Support for Policy towards Sustainability by Material Flow Accounting, Proceedings of the ConAccount Conference, 11-12 September 1997, Germany, Wuppertal Institute for Climate, Environment and Energy, Wuppertal.

RITTHOFF, M.; ROHN, H. & LIEDTKE, C. (2002): Calculating MIPS: Resource productivity of products and services. Wuppertal Spezial 27e, Wuppertal Institute for Climate, Environment and Energy. http://www.wupperinst.org/uploads/tx_wibeitrag/ws27e.pdf.

SCHMIDT-BLEEK, F. (1992): MIPS - A Universal Ecological Measure. Fresenius Environmental Bulletin 2, 407-412.

SCHMIDT-BLEEK, F. (1994): Wie viel Umwelt braucht der Mensch? MIPS – das Maß für ökologisches Wirtschaften. Birkhauser, Berlin, Basel.

SCHMIDT-BLEEK, F.; BRINGEZU, S.; HINTERBERGER, F.; LIEDTKE, C.: SPANGENBERG, J.; STILLER, H. & WELFENS, M. (1998): MAIA. Einführung in die Materialintensitätsanalyse nach dem MIPS-Konzept. Birkhauser, Berlin, Basel.

SCHOER, K. & SCHWEINERT, S. (2005): Primary material flow accounts by branches and material categories for Germany, in: Ninth Meeting of London Group on Environmental Accounting – Proceedings and papers, 22.-24.09.2004 in Copenhagen, Denmark, Copenhagen.

SCHOER, K. (2006): Calculation of direct and indirect material inputs by type of raw material and economic activities, Paper presented at the London Group Meeting 19 – 21 June 2006. http://www.destatis.de/download/e/ugr/London-Group-2006_Raw_material.pdf

SCHÜTZ, H.; MOLL, S. & BRINGEZU, S. (2004): Globalisation and the Shifting Environmental Burden: Material Trade Flows of the European Union – Which Globalisation is Sustainable? No. 134e, July, Wuppertal Institute for Climate, Environment and Energy. http://www.wupperinst.org/uploads/tx_wibeitrag/WP134e.pdf.SERI (2008): Global Natural Resource Consumption. Vienna. http://www.seri.at/.

SERI – Sustainable Europe Research Institute (2006): The Ecological Footprint. Vienna. www.seri.at.

SERI – Sustainable Europe Research Institute (2008): MFA Visualisation Tool. Vienna. www.materialflows.net.

SPANGENBERG, J.; FEMIA, A.; HINTERBERGER, F. & SCHÜTZ, H. (1998): Material Flow-based Indicators in Environmental Reporting. Environmental Issues Series. No. 14. European Environmental Agency, Luxembourg.

STATISTIK AUSTRIA (2007): Statistisches Jahrbuch, Außenhandelsbilanz mit den Import- und Exportmassen von 262 Materialgruppen. Wien.

STATISTIK AUSTRIA (2008): Materialflussrechnung, im Auftrag des BMLFUW. Erstellt am 22.08.2008. www.statistik.at.

SWISS FEDERAL COUNCIL (2008): Sustainable Development Strategy: Guidelines and Action Plan 2008-2011. Report of 16 April 2008. http://www.are.admin.ch/themen/nachhaltig/00262/00528/index.html?lang=en.

UMWELTBUNDESAMT (2009): REISINGER, H.; SCHOELLER, G. & MUELLER, B.: Executive Summary - RUSCH -Resource Potential and Environmental Impact of the Heavy Metals Lead, Cadmium and Mercury in Austria. Umweltbundesamt, TU-Wien, Vienna, Klagenfurt. (in preparation).

VAN DER VOET, E.; VAN OERS, L.; MOLL, ST.; SCHÜTZ, H.; BRINGEZU, ST.; DE BRUYN, S.; SEVENSTER, M. & WARRINGA, G. (2005): Policy Review on Decoupling: Development of indicators to assess decoupling of economic development and environmental pressure in the EU-25 and AC-3 countries. University of Leiden, Leiden. www.leidenuniv.nl.

VITOUSEK, P. M.; EHRLICH, P. R.; EHRLICH, A. H. & MATSON, P. A. (1986): Human Appropriation of the Products of Photosynthesis. BioScience 36(6), 363-373.

WALDMÜLLER, B. (2001): Physical Input-Output Tables of the Federal Statistical Office. Paper presented at the Workshop of the ConAccount Material Flow Accounting Network, Stockholm, April. http://www.account2001.scb.se.

WEBER J.-L. (2007): Implementation of land and ecosystem accounts at the European Environment Agency. Ecological Economics 61 (2007) 4, p. 695-707.

WEBER, L. & ZSAK, G. (2006): World Mining Data - Minerals Production. BMWA - Bundesministerium für Wirtschaft und Arbeit, Volume 21, Wien.

WEISZ, H. & DUCHIN, F. (2006): Physical and monetary input–output analysis: What makes the difference? Ecological Economics 57, 534-541.

WEISZ, H. (2006): Accounting for raw material equivalents of traded goods. A comparison of input-output approaches in physical, monetary, and mixed units. Working Paper. No. 87. IFF/Social Ecology, Vienna.

WEISZ, H.; EISENMENGER, N. & SCHAFFARTZIK, A. (2008): Methodische Weiterentwicklung der Brechnung des Rohmaterialbedarfes im Außenhandel. Institut für Soziale Ökologie, IFF, Wien.

WEISZ, H.; KRAUSMANN, F.; AMANN, CH.; EISENMENGER, N.; ERB, K.-H.; HUBACEK, K. & FISCHER-KOWALSKI, M. (2005): The physical economy of the European Union: Cross-country comparison and determinants of material consumption. IFF, Social Ecology Working Paper 76, Wien.

WEISZ, H.; KRAUSMANN, F.; AMANN, CH.; EISENMENGER, N.; ERB, K.-H.; HUBACEK, K. & FISCHER-KOWALSKI, M. (2006): The physical economy of the European Union: Cross-country comparison and determinants of material consumption. In: Ecological Economics 58(4), pp. 676-698.

WRIGHT, D. H. (1990): Human impacts on the energy flow through natural ecosystems, and implications for species endangerment. Ambio 19(4), 189-194.

9 ANNEX A: INVENTORY OF COUNTRY ACTIVITIES

Table 5: Resource and material flow accounts - main characteristics and scope (OECD 2008d, additions by authors)

	Type of activity (a)			**Other closely related work (b)**	**Reference framework (c)**	**Comments**
	EW-MFA	**PIOTs**	**SFA**			
Austria	X	X	X ad-hoc	X e.g. NAMEA	EW-MFA: Eurostat	Many MF studies (official and academic). PIOTs: methodological work, SFA, NAMEA and other specific MFA
Belgium	X	-	X	X eIO-model	EW-MFA: Eurostat & WRI	EW-MFA: regional level, Flanders & Wallonia. SFA: ad-hoc project (AL, Cr, Cd, N-compounds) & model for dynamic SFA (Flanders). eIO model: gradual development in Flanders
Czech Republic	X	X ad-hoc	-	X NAMEA pilot	EW-MFA: Eurostat	NAMEA for air emissions (pilot project). PIOTs carried out within research projects
Denmark	X pilot	X pilot	-	X NAMEA	EW-MFA: Eurostat	PIOTs: pilot project for 27 industries (1600 & 1800 products in 1990 and 2002). NAMEAs: regular activity for energy, water, air, oil&gas reserves, waste (physical part).
Finland	X	X	X	X NRA	EW-MFA: Eurostat	PIOTs: NAMEA type aggregation of branches for industry. SFA: sectoral LCA for mining, forest, metals, packaging industries, energy, water, waste water treatment, paper, nutrients. NRA: forests.
France	X	-	-	X NAMEA, NRA	EW-MFA: Eurostat	NRA: forests and water. NAMEA: air emissions by 40 branches and energy. MFA: regular activity starting from spring 2007.
Germany	X	X	-	X NAMEA	EW-MFA: Eurostat	Full fledged Material & Energy Flow Information System (MEFIS) based on PIOTs (breakdown by 60 branches) by NSO. Calculation of Raw Material Equivalents. Plus research work by NSO and Wuppertal Institute.
Hungary	X pilot		-		EW-MFA: Eurostat	Plans to use MFA concepts in government policy making.
Iceland	-	-	-	X NRA		Other: Water flow accounting (link to energy) & some work on soilerosion.
Ireland	X	-	-	X NRA,	EW-MFA: Eurostat	Time series of EW-MFA. eIOA for 2003 with time series under development. Environmental accounts for emissions to air, water and waste1990-2005 .
Italy	X	X pilot	-	X NAMEA	EW-MFA: Eurostat	PIOT: feasibility study done; pilot-exercise realise. NAMEA resource intake and air emissions by industry.
Luxembourg	-	-	-	X NAMEA		No official plans for MFA work so far.
Netherlands	X ad-hoc	-	X	X NAMEA		EW-MFA: joint international research project. SFA: many studies since 1990; heavy metals, nutrients, organochlorines. Other: NAMEA, dematerialisation, focus: energy content and environmental impacts of material and substance flows
Norway	X pilot	-	X	X NRA		EW-MFA: 2006-7 pilot project. SFA: energy air, hazardous substances, waste.
Poland	X pilot	-	-	X NAMEA	WRI	EW-MFA: preliminary study in 1998-99; WRI framework. Systematic MFA under consideration by government (eco-efficiency programme in National Environmental Policy). NAMEA: air.
Portugal	X pilot	X pilot	-	X NAMEA	EW-MFA: Eurostat	EW-MFA: PIOTs (eIO-LCA): stand alone research study.
Slovak Republic	X	-	-	X NRA	EW-MFA: Eurostat	EW-MFA: systematic work since 2005 (Minister Resolution) via a pilot project of the EPA. Other: individual accounts for watr, mineral ores, raw materials, oil, coal, fuels, wood, construction materials etc. at national level.
Spain	X	-	-	X	EW-MFA: Eurostat	Other: water, forest, air emission accounts. MFA: also by Basque country government.

	Type of activity (a)			**Other closely related work (b)**	**Reference framework (c)**	**Comments**
	EW-MFA	**PIOTs**	**SFA**			
Sweden	X pilot	-	X	X	EW-MFA: WRI, ConAccount, SEEA	SFA: air + water emissions (focus on metals) by universities and municipalities at local level; ad hoc study by Chemicals Inspectorate (appr. 200 substances). Other: energy related materials, hazardous substances (NAMEA framework).
Switzerland	X	-	X	X	EW-MFA: Eurostat	EW-MFA: yearly since 2003. NAMEA Greenhouse gas: Pilot 2005 (emissions 2002), 2009 (emission 2005) and yearly since 2010. SFA and regional or micro-level MFA: various studies by consultant firms, universities, research institutes (mostly related to waste management).
Turkey	-	-	-	X pilot		Other: SEEA supply use tables (inland water). NAMEA air; stand-alone study (1999-2002)
United Kingdom	X	X	X	X NAMEA	EW-MFA: Eurostat	EW-MFA: Wuppertal Institute pilot study; plus complete UK overview mass balance. PIOZ: regional, product based using PRODCOM; ad-hoc NGO work. SFA: studies by waste management industry as part of landfill tax credit scheme. NAMEA: air and energy

Notes:

a) EW-MFA: Economy-Wide Material Flow Accounts or mass balances; PIOTs: Physical-Input-Output Tables; SFA: Substance Flow Analysis

b) Other: all other relevant activities, including individual flow accounts and other Natural Resource Accounts (NRA), National Accounting Matrix including Environmental Accounts (NAMEAs), environmental Input Output analysis (eIO), etc.

c) SEEA: System of Integrated Environmental and Economic Accounting

Table 6: Availability of material flow indicators (OECD 2008d, additions by authors)

	Economy wide material flow indicators					Comments
	DE	**DMI**	**DMC**	**TMR**	**Other**	
Austria	X	X	X		PTB, DRD, NAS	All related to GDP, population and area
Belgium		X	X	X	PTB, DPO, DMO	Related to GDP
Czech Republic	X	X	X	X	PTB, DPO, DMO, TMC, TDO, NAS	
Denmark	X	X	X	(X)	PTB	
Finland		X	X	X	TMC	
France		X	X			
Germany		X	X		Abiotic raw materials productivity, PTB, DPO, NRS	
Hungary	X	X	X	(X)	PTB, (TMC)	
Ireland	X	X	X		PTB	All are related to population and GDP
Italy	X	X	X	X	PTB, PTBIF, TMC	
Netherlands			X			DMC environmentally weighted
Poland		X		X		
Portugal		X	X	X		
Slovak Republic	X	X	X		PTB	
Spain		X	X	X	DPO, DMO, TDO, TMO, TMI, TMC, NAS	
Sweden		X	X	(X)		TMR adhoc
Switzerland	X	X	X	X	PTB, material productivity and intensity, DPO, NAS	
United Kingdom		X	X	X	PTB	

DE Domestic Extraction
DMC Domestic Material Consumption
DMI Direct Material Input
DMO Direct Material Output
DPO Domestic Processed Output
DRD Domestic Resource Dependency
NAS Net Additions to Stock
PTB Physical Trade Balance
PTBIF Physical Trade Balance including Indirect Flows
RMTB Raw Materials Trade Balance
TDO Total Domestic Output
TMC Total Material Consumption
TMI Total Material Input
TMO Total Material Output
TMR Total Material Requirement