Part III:

Focus Groups

Short Review & Focus Group Reports:

Short Review of the MFA work presented

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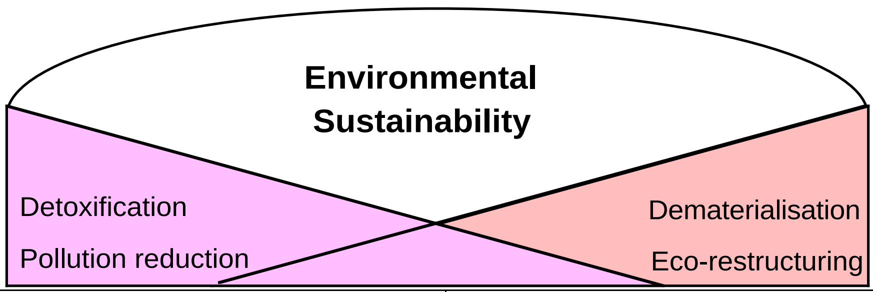
The MFA work presented at the workshop and documented in this volume was reviewed in a preliminary way to describe different as well as common elements of the various approaches.

The *subjects* of accounting are chemically defined substances (e.g. carbon or carbon dioxide) on the one hand and naturally or technically compound or "bulk" materials (e.g. coal, wood) on the other hand. In this text the latter will be termed "material<u>s</u>". The term "material flow" still embraces substances and materials.

All the work presented may be assumed to contribute to the implementation of the environmental sustainability concept (TABLE 1). However, the strategies to pursue that aim are basicly quite different. On the one hand, the "detoxification" of material flows and the reduction of environmental pollution is traditionally assumed to be an important goal (see e.g. Hansen; Udo de Haes et al.). On the other hand, the "dematerialisation" and the "eco-restructuring" of the industrial or societal metabolism is increasingly being advocated as a pre-requisite for environmental sustainability (see e.g. Bringezu; Fischer-Kowalski). Consequently, either the impact potential per unit of material flow or the volume and structure of material flows attract prior attention. In the end, both strategies will be necessary to foster a sustainable development, and they may be addressed as complementary.

Based on these different views, however, the starting point for MFA may be different. Although in practice a continuum of different approaches seem to be followed two basic types of accounting may be distinguished according to the *objects* of primary interest.

Table 1: Basic types of Material Flow Accounting (MFA)

Conceptual Target Basic Strategies				
Accounting Type	I		II	
Objects of primary interest	Specific Environmental Problems related to certain impacts per unit of flow of		Problems of Environmental Unsustainability related to volume and structure of the throughput of	
	Substances	Materials	Sectors	Regions
	e.g. Cd, Cl, Pb, Zn, Hg, N, C, CO_2, CFC	e.g. wooden products, energy carriers, moved masses, biomass, plastics	e.g. production sectors, chemical industry, construction	e.g. total or main throughput, mass flow balance, global material input
	within certain compartments, sectors, regions		associated with substances or materials	

Type I starts with specific problems that are related to selected substances or materials. The flow of eco-toxic substances such as heavy metals is studied (e.g. Dahlbo/Assmuth; Daxbeck et al.; Lassen et al.; Hansen/Lassen; Hansen; Maag et al.; Schönbauer) because they are associated with environmental problems for instance by accumulation. The flow of nutrients like nitrogen is accounted (e.g. Daxbeck et al.; Reiner et al.) because it may be critical due to eutrophication. The flow of carbon is studied (e.g. Daxbeck et al.; Flugsrud et al.) because it is e.g. associated with global warming. The flows of chlorinated substances are quantified (e.g. Obernosterer/Brunner; Tukker/Kleijn) because they are rendered to be critical for various pollution problems. Selected flows of materials may also be of interest. Energy carriers (e.g. Gielen/Kram), moved masses (e.g. Douglas/Lawson), plastics (e.g. Fehringer/Brunner), wooden products (e.g. Mäenpää/Juutinen), biomass (e.g. Haberl), and aluminium (e.g. H. Moll) may be associated with certain environmental pressures and/or may be studied in order to optimize its economic use or improve recycling and cascading strategies. Studies relating specified emissions to the production of base materials (e.g. Gielen/Kram) or to the various sectors of industry (e.g. Norris; Hohmeyer et al.) lead to the next type of accounting.

Type II starts with the question whether the volume and structure of the throughput of selected sectors or regions is sustainable. For instance, industrial sectors (e.g. Windsperger), chemicals production (e.g. Zangerl-Weisz), or construction (e.g. Glenck/Lahner, Schandl/Hüttler) are studied with respect to their throughput of substances or materials. Cities, regions or national economies are studied with regard to selected material flows (e.g. Foxon/Leach; Spapens), the total material throughput (e.g. Fischer-Kowalski/Winiwarter; Payer et al.) and/or the global material input (e.g. Bringezu; Moriguchi; Schütz). One major aim of those studies is the derivation of indicators for environmental pressure. This does not only refer to total mass throughput but - for instance - also to the relation of renewable to non-renewable inputs in order to indicate structural properties of the regional metabolism.

Studies of both types comprise elements of a general scheme of MFA.

Target questions are defined according to the primary objectives. In both types, it has to be determined which flow categories will have to be accounted in order to quantify volume and path of the flows, and to find out those flows which are most relevant for the problems of primary interest, and those factors most responsible for these flows.

The *scope* defines the spatial, temporal and sometimes functional extent of the studied objects. The categorized flows are studied along their path that is related to *spatially* defined compartments or regions or to functionally defined industrial sectors. The flows are always accounted based on a temporally defined period. The scope may be similar for type I and type II.

The *system boundary* defines the start and the end of the material flows which are accounted. It is - at least - partly determined by the scope but may comprise additional functional elements, e.g. the border line between the environment and the economic sectors of a region. Scope and system boundary are not necessarily identical, especially when regionally limited accounts are combined with product chain oriented accounts. For instance, if the transnational material input of a national economy is determined (e.g. Bringezu, Moriguchi, Schütz) the scope remains national while the system boundary is defined functionally on a larger scale.

The *results* of MFA of both type I and II are usually presented as an overview of the flows within the studied system, but they may also be differentiated to detailed descriptions in order to focus on essential sections of the flow network. The results are always interpreted in the way that the flows essential for the problem of interest are revealed. For type I studies these are the flows most relevant for a specific environmental problem. For type II studies these are the flows most critical for the volume and structure of the systems throughput as regards sustainability. This may include the derivation of indicators for the problem(s) described, e.g. material intensity. For both type I and II studies the results are generally intended to serve as a basis for planning and control of effective measures for material management (to solve the problems of interest). Therefore, processes, sectors, and actors which determine or may influence the problem flows are indicated by MFA studies.

Interlinkages between different material flows are not always accounted for. According to the primary interest the accounting of type I is usually limited to the selected material(s) associated with the specific problem of interest. However, the interlinkage with other flows may be revealed as a result of the study, e.g. the coupling of cadmium with zinc and phosphate production (e.g. van der Voet/ van Oers). If materials are chosen as subjects of type I accounting, different substances are implicitely studied in a compound way, whereas the analysis of the interlinkage to other materials flows is usually also limited. If the interlinkage of material flows is not considered properly this may result in severe problem shifting (e.g. van der Voet/ van Oers). And in general, it is not easy to account all material flows that may be of relevance (e.g. Heijungs). In a usually pragmatic approach, these problems are tackled by the studies of Type II. They are intended to provide not only information on the overall throughput of the sectors or regions but shall also get insight into the structure of the inputs and outputs thus revealing the interlinkages at least of the main material flows.

The interaction of material flows and economic activities has been the subject of various approaches of an *integrated environmental and economic accounting* (e.g. Bringezu; Hohmeyer et al.; Mäenpää/Juutinen; Radermacher/Höh; S. Moll/Femia; Moriguchi; Norris; Payer et al.; Schütz). The data basis used for MFA has often been installed for economic purposes. This has the advantage that MFA can be used to relate physical to economic data in order to compare environmental and economic performance. However, in many cases a lack of harmonization between existing base statistics is seen as a critical impediment for comparative work. In general, linking economic and substance flow models is faced with severe difficulties which may be solved to a certain extent by the use of materials based accounting (Guinée et al.).

Two *main techniques* of MFA may be distinguished: (1) Retrospective bookkeeping is used for monitoring and evaluating material flows with regard to the planning and control of improvement measures (most of the MFA work presented belongs to that group). (2) Prospective modelling (static and dynamic) and scenario techniques are used to support refined planning and the provisional evaluation of specific control measures (e.g. Gielen/Kram, Hohmeyer et al.).

Some contributions did not present MFA results but described some interesting options to include MFA into ongoing work on the analysis and the reporting of municipal performance with regard to sustainability (Valentinelli; Runge), or expressed their expectations of the policy relevance of MFA (Berkhout).

Some *interesting features* for future work have been presented:

(a) So far, MFA has mainly been based on deterministic calculations resulting in fixed values. The variance of natural and technological processes measured by primary data is largely been lost during aggregation. This can be overcome by the integration of elements considering contingency into MFA (e.g. Lassen et al.; Huele/Kleijn).

(b) The development of physical input-output-tables has been proposed by several authors (e.g. Hohmeyer et al., S. Moll/Femia, Mäenpää/Juutinen). It may be regarded as an adequate instrument for integrated environmental and economic accounting that is based on statistics that are either already available to a large extent or that could be made available with reasonable effort in the future.

(c) As regards the relation of the different dimensions of sustainability the interaction of material flows and economic activities is already a matter of integrated analysis. However, the relation to social parameters is still at the beginning (e.g. Fischer-Kowalski/Winiwater; S. Moll/Femia). Especially the integrated analysis of the ecological, economic, *and* social dimensions of sustainability still awaits thourough tackling in order to provide a broad basis for policy support.

Focus Group Report:

Towards a General Framework for MFA I: National Material Accounting

Moderation: M.Fischer-Kowalski

Participants: Aldo Femia, Norbert Fenzl (protocol), Helmut Haberl, Nick Marks, Henri Moll, Helmut Schütz, Iddo Wernick

(For the first phase of the session there were also participating Emanuel Glenck, Stefan Toisern, Tim Foxon, Karsten Runge, Sverker Molander, Simon Molenaar, Helga Zangerl-Weisz. The group of 16 participants proved to be too big and too heterogenous to be able to arrive at a common definition of the task at hand. So it agreed to split up, and the above members formed a second group chaired by E.Glenck to discuss MFA on a regional level. They delivered a separate report).

1 Procedure

It was agreed to attempt a comparison of the national material flow accounts for Austria (Fischer-Kowalski, Haberl), Germany (Schütz) and USA (Wernick) that had been produced, or that were about to be produced (such as for Italy, Femia) with the cooperation of the researchers now assembled in this group, to try to find communalities and differences and, where possible, agree upon preferable definitions and procedures on the basis of past experiences. The rest of the group should act as a critical audience and secure clarity and consistency. The focus of the discussion should be

- boundaries of socio-economic systems: how to define them theoretically and operationally,
- material flows: how to define them, classify them and what to relate them to.

Major criteria for the quality of possible definitions and procedures should be comparability (internationally and over time) and communicability: It was agreed that the power of the approach for influencing policies towards sustainability would strongly depend upon these criteria.

2 System boundaries, system compartments and stocks

It was easy to agree that system boundaries had to be specified functionally rather than territorially: water does not enter a country‘s socio-economic system because a river crosses the national border, but because it is drawn into a socio-economic use. It was also clear that all studies at hand defined boundaries between the national socio-economic system under investigation and other socio-economic systems in the way national economic accounting does, by defining imports and exports to and from the national economy. The second kind of (functional) boundary were to be defined between the socio-economic system (the term coined by U.H. de Haes, "physical economy", was also used) and its natural environment.

For this distinction general systems theory was accepted as helpful in looking at system compartments as stocks and then identifying the flows required for the production/reproduction of those stocks. It was perfectly clear that all studies under consideration had seen as stocks

- the human population of the nation state
- the (long-lived) technical infrastructure such as buildings and machines

Although an agreement could be reached about a third compartment, that is

- the livestock of animals (agricultural and domestic),

it was also seen that national material flow accounts often handled the flows associated with this compartment inconsistently. A typical inconsistency arises if both crops needed for feeding livestocks, and meat & milk are counted as "inputs from the environment" (USA, Japan). This amounts to double counting. If the livestock is a compartment of the socio-economic system, its fodder has to be looked upon as input from the environment (including the amounts consumed by grazing, which is also often not properly done), while meat, milk and eggs have to be considered transfers within the socio-economic system. As an output to the environment not only animal manure, but also the carbon emitted by animal breathing would have to be considered. This was seen as a point where agreement and consecutive methodological standardization should and could be reached.

A more extensive discussion was devoted to the question whether crops/timberland, or even agricultural/forestry topsoil, should be considered as a compartment respectively stock of the socio-economic system. In favor of inclusion it was argued that these systems are strongly molded by human influence (some "agricultural" production processes, such as glasshouse and hydroponics, do indeed much more resemble industrial production than natural processes), and that they are at least partially reproduced by human labor. As con‘s it was mentioned that such a definition would reduce human nutrition to the trophical level of plants (only mineral inputs would be considered as inputs from nature, the rest as transfers within the economy); and that in the realm of plants it tends to be very difficult to distinguish between "within" and "outside of" the socio-economic system (how about a tree that grows in a neglected garden because nobody cares to cut it down?). Obviously so far no national MFA has drawn the boundary such as to include crops/timberland.

It was proposed to check the consistency of input-output-relations not only on the overall system‘s level, so that the sum of inputs should equal the sum of outputs plus change in stocks, but also to guard consistency for each compartment in the way that each compartment‘s inputs would also equal outputs plus stock change. By doing so, mistakes due to overlooking certain flows or doublecounting could be avoided.

3 Which flows should be considered?

The first part of the discussion was devoted to the problem of "overburden" or "unused materials" and whether they were to be included in the overall material input. As far as the three material flow analysees under consideration go, neither the American nor the Austrian example included data on overburden (i.e. overburden from mining, or soil moved by erosion, etc.), but the study on Germany did, calculating separately but also adding up "used" and "unused" materials (the latter amounting to several times as much as the former).

First the discussion focussed on the question whether "unused" or "translocated" materials had an environmental impact in the same order of magnitude as the used materials; and, furthermore, whether the environmental impact of unused materials was best expressed in weight (or rather in some other measure, such as area concerned). No definite consensus was reached here, but it became clear that the environmental impact of activities like mining went considerably beyond the effect represented by the (relatively) small amount of metal ores extracted, for example, and, moreover, that the externalization of these activities into Third World countries ought to be made visible by MFA. So considerations of environmental impact could not provide with a decisive criterion on how to handle overburden flows.

Next, more practical aspects such as communicability, comparability and costs were considered. Overall material throughput as a parameter was considered particularly valuable for its communicability to the wider public, and this advantage should be preserved. This communicability was, at least in part, attributed to relative simplicity. The following graph conveys an idea of how the relationship between scientific accuracy/differentiaton and communicability might be modelled, and it also should help to illustrate a recommendation to place this method in an interval of scientific accuracy where communicability may be at a maximum.

Explanation: Below the "minimum standard" of scientific accuracy and differentiation something cannot be considered scientifically acceptable; below the "minimum standard" on the y-axis something cannot be considered "communicable". This model assumes a curvilinear relationship where in the lower part of the scale an increase in scientific accuracy and differentiation supports communicability, a further increase makes it an exclusive realm of experts, though, and in between there may be some optimum.

Including overburden in a total is felt to put an unneccessary stress upon the communicability of the concept. But it should, seperately, be accounted for.

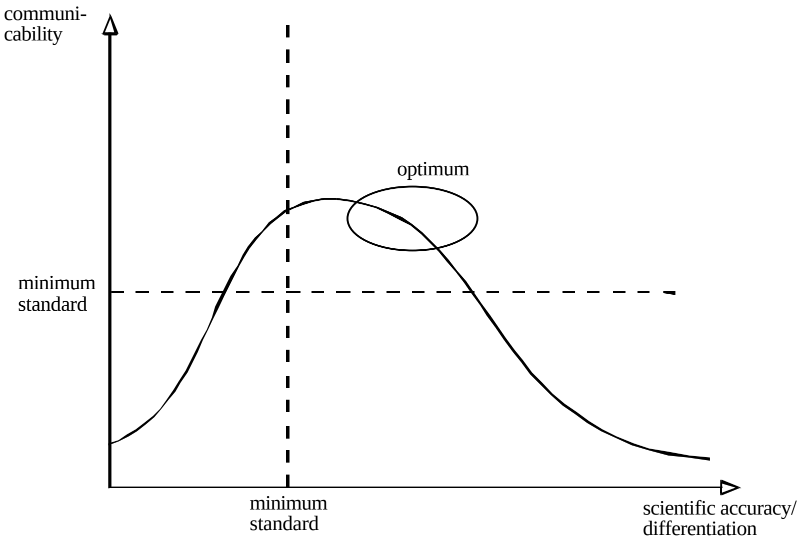


Figure 1: A model for the latent relationship between scientific accuracy/differentiation and communicability

Similar considerations apply to comparability. One aspect is the comparability of the model: Overall material flow accounting as a model corresponds very well to the much more widely used model of (monetary) national accounting, and for this purpose it makes sense to define a "physical economy" in close analogy to the "monetary economy" as modelled in the GDP, for instance. Some participants, though, reminded that the resulting indicators (t/$) would not indicate pressures upon the environment, but rather the efficiency of the economy. Even more important, though, is the comparability of data, internationally and intertemporally. The data base for material flows directly associated to economic transactions (as is the case with "used materials") can be expected to be much more reliable and consistent than that for the overburden ("unused materials"), and in most cases the latter will only be available as estimates or estimated multipliers for observed values.

Finally, an economic use of the increasingly scarce resources available for statistics was drawn into consideration. It was felt that the barriers for as many countries as possible to generate national material accounts should be kept as low as possible. These considerations resulted in the recommendations summarized in figure 2.

Quite another issue that should be resolved by international standardization is the water content of materials, particularly of biomass. Some studies use fresh weight, some standardize to 15% (a water content typical for timber and grains), some use dry-weight-measures. Due to lack of time this was not discussed in detail, but generally it was felt the need and the possibility of standardization.

	record	add up into total	use as overall indicator*
used materials (excluding water and air)	yes	yes	yes
water, air	yes	keep separate	yes, separately
unused materials (overburden)	yes	???	no; rather: ratio to used materials (multiplier)

* this indicator can be expressed as t/capita, or as t/GDP (the latter was challenged by some members of the group)

Figure 2: Recommendations for the input side (material extraction) of overall national material flow accounting

Finally the classification of (used) material flows was discussed. In reviewing the three examples represented in the group it became clear that the classifications used were very similar, the justifications and the level of disaggregation sometimes a little different, though. Apart from air and water there was always distinguished between

- biomass: broken down into timber, agricultural products and hunted fish/game
- fossil fuels
- other minerals: sometimes broken down into metals, industrial minerals, construction minerals.

It was felt that with a comparatively small amount of effort a harmonization could be reached in this respect.

So, finally, the group agreed that aggregated material flows on a national level are a meaningful indicator that in the future may be reliably and comparably be measured for many countries. But there also was a common understanding that such an indicator could by no means summarize all, or even all the most important, aspects of the pressures upon the environment a national economy/society exerts; additional indicators would be needed.

Focus Group Report:

Towards a General Framework for MFA II

Moderation and protocol: Emmanuel Glenck

Participants: Peter Daniels, Timothy Foxon, Sverker Molander, Simon Moolenaar, Karsten Runge, Helga Zangerl-Weizs

Initially, the following topics were supposed to be discussed in the working group "Toward a General Framework for MFA":

a) system boundaries
b) (sub)systems, compartments, aggregation, disaggregation
c) consistency of data (inputs, stocks, outputs)
d) comparability of data in space and time
e) criteria for weighting masses

Due to the relatively short time at its disposal, the working group decided to focus on the first topic, namely on the problems related to the definition of system boundaries. As pointed out several times during the discussion, this topic is closely related to the other ones e.g. b), c) and d). The problem of "weighting" mass flows was not considered in the discussion.

One of the conclusions of the discussion was that MFA (material flow accounting or material flow analysis) should include the assessment of *flows* (transport of mass during a given time interval into or out of a specified geographical area) as well as the quantification of existing *stocks* (reservoirs of mass in a process during the time interval) for the total mass of goods or substances (chemical elements or compounds) covered by the study. This method may be applied at different levels and on different systems (waste treatment plant, coal plant, agriculture, buildings and networks, paper industry, city, region, country etc.) or materials (e.g. plastics, nutrients, heavy metals).

A clear definition of the variables to be assessed in the system (goods, materials, concentration, stocks, flows, transfer coefficients) represents in many cases the first problem to be solved. One has to contend with not unified terminology, language problems, the definition of systems and subsystems and the description of mathematical or qualitative relationships between the variables and/or system boundaries.

Generally, two kinds of system boundaries have to be set: (i) the *time boundary* (interval: usually one year) and (ii) the *space boundary* (physical boundary: e.g. factory, region, nation, industrial sector). A given system boundary corresponds to a specific question; this often makes it impossible to compare results from different studies of the same system:

- <u>space boundary:</u> it is problematic to consider the environmental impacts *inside* or *outside* of the system boundaries (functional and geographical); the waste reduction measures should include information about production processes that are often not part of the system ("Where does this good come from?"). A further criterion to set up space boundaries is the ability to apply policies effectively within the given system, which is related to the "jurisdiction" over a certain area (e.g. government). Furthermore, difficulties to consider the environmental impacts outside of the system (e.g. the life-style of the industrialised countries gives environmental impacts in other countries far away in time and space, and not just impacts *at home* or impacts related to environmental problems like stratospheric ozone reduction and global warming).

- time boundary: the time unit generally used in MFA at a regional level is one year. Extrapolation to the long term is not possible due to missing time series (dynamic modelling). Most of the systems are described by a static model.

It was pointed out in the group discussion that one has to consider the links between the goal and scope of the study and the choice of system boundaries (e.g. trying to raise awareness or describing a certain flow related to a business sector). The following questions have to be answered:

- What is the purpose of the study?
- Which are the questions to be answered?
- Which system boundaries are of relevance?

The definition and delimitation of system boundaries (fixing of limits) have been discussed from different view points:

a) purposes of the study
b) limitations of the modelling
c) differences between functional and structural boundaries
d) role of primary data

a) Purposes of the study (or system)

The purpose of the study defines the questions, the system to be studied and the choice of aggregation level (accounting level). The group discussed among others the following points:

- data availability
- ability to apply a given policy effectively within the system considered
- environmental impacts within the system
- data comparability within the system, at national and international levels
- relationships between inputs, stock variations and outputs
- accumulation and depletion rates
- time frames

b) Limitations of the modelling of material flows:

It is possible to build more or less elaborate models without proper foundation on data. Just boxes and arrows may be used as heuristic tools when trying to define the system but the challenge for flow analysis is to feed the appropriate models with data representing the real processes (mass flows and stocks). For instance, the use of aggregated data may make it very hard to relate material flows to environmental impacts, since information has been lost in the aggregation process. On the other hand, data on various flow of materials or substances, regardless of amount or accuracy, are not as powerful for understanding the processes as data connected to a model. Data without a model and a model without data are both ineffective.

It is important to achieve a good match between the system model and the available data since it must in principle be possible to trace both flows of material and energy from input to output through the various subsystems of the model. Due to limitations in data availability rather coarse models are mostly the result of MFA studies. This is however a problem that may be overcome.

c) Differences between functional and structural boundaries:

The functional boundaries (e.g. fertiliser industry) do not necessarily fit to the structural ones (e.g. geographical, geological). This can lead to problems like low comparability between different studies (this point was only mentioned but not further discussed in the group).

d) Role of primary data:

The need for less aggregated data (e.g. as input for modelling purposes) was emphasised during the discussion. In principle, there are three categories of data sources used for MFA purposes:

(a) primary data from direct technical measurements

(b) secondary data (information from administrative records and publications)

(c) tertiary data (expert knowledge, estimates based on non-published data)

Primary data include in general one or more stages of statistical information, like estimation of mean, standard deviation or confidence intervals. The experience shows that direct measurements on most input or outputs are rarely available for the system chosen. The confidence intervals of all data sets (primary, secondary, tertiary) has to be assessed to estimate the quality of the measurements. The conventional approach in MFA is to combine data from administrative records with indirect or hybrid data from models or studies done at different times and places for other purposes (generated by other MFA procedures). This "cross-checking" may cause problems in:

- <u>Data reconciliation</u>: In the case where both inputs and outputs are assessed for a given process, there may be a difference between them. This difference can either be attributed to a change in the stock and/or equalised in order to balance the process.
- <u>Estimation of unmeasured flows</u>: It is not always possible to assess each input or output respectively for a given process. In this case, one has to estimate the missing flux (difference between in- and outputs). A topic that is sometimes overlooked is the issue of the quality in putting together a mass balance for a network of processes on the basis of direct and indirect data. The main obstacle for analysing material flows, is the problem connected to the development of expressions for the uncertainty of the measured as well as the unmeasured flows (modelling: equations for system identification and uncertainties, optimisation procedure, etc.).
- <u>Transfer coefficients</u>: According to the data (e.g. availability, quality, uncertainties, specificity), transfer functions may be simplified to transfer coefficients which means a loss of information about the system behaviour. If the transfer coefficients are not available, the links between inputs, stocks and outputs within a system or a process are not identified (functional relationships of the system theory). This means that the sensitivity analysis can not be performed (identification of the most relevant variables to monitor).
- <u>Availability</u>: Data scarcity, no information available or missing data are a problem. The interpretation of results may fail due to missing data (i.e. unavailable yet, non recorded). Its relevance and significance have to be assessed from case to case. For example, in the case of a process where no stock variation occurs and all in- and outputs are known with exception of one (in- or output), the unknown flux is obtained from the overall difference between inputs and outputs.
- <u>Actualisation</u>: The use of current data is recommended but increases the amount of work needed to gather data. If material flows are considered to be of great importance it is however possible to create systems similar to existing statistical systems used to handle economic data (national accounting, etc.). The data is for example collected once, but not always actualised afterwards (time series: a periodic collection is necessary to check the evolution and the improvement/degradation of the situation). The development, maintenance, actualisation of data and correction of wrong or obsolete data is often linked to a high time and cost expenditure. Changing the operating system can lead to a massive loss of data (e.g. the old data support is not readable any more).
- <u>Transparency</u>: The reference to original data-sources are of scientific interest since it should be possible to check data and review methods for data gathering. Low transparency of secondary data, without references, may be a problem resulting in less reliable studies.
- <u>Form and units</u>: The value itself may occur in different forms (i.e. mean, min-max. range, standard deviation, distribution) giving problems and high uncertainties when estimating

flows. Units may also be different. Efforts for standardising environmental measurements and the quantification of material flows are probably a higher priority than standardising the design of models for MFA.

- Consistency and reliability: Data not consistent, overlapping, gaps, data set not up to date, data not reliable or not complete represent often a problem.
- System: The data is often region specific, which means that it can not be applied to other regions (data not representative). We cannot always assume that data gathered in one region can be used for studies of flows in other regions: one of the points of mass flow analysis is to compare different regions/systems.
- Time: The samples are representative for a given period of time (hour, day); an extrapolation to the balance unit (year) can be unreliable.
- Regional level: Industry and trade statistics are not available yet at a regional level in most of the cases.
- Adequacy: Statistics are not always adequate for regional MFA purposes (high aggregation, partial data, different structure, no inter- or intrapolation possible). This can influence the setting up of the system boundaries.
- Aggregation: If the aggregation level is different (e.g. code position in a given statistical record), no comparison with other data sets is possible due to lacking compatibility. If the raw data is not available (high aggregation level), a "top-down" analysis can not be performed.
- Definition of the objectives and questions: The comparison between two studies may be rarely possible because of different objectives, depending on the purposes and the specific questions to be answered by the study.

As far as data quality for MFA purposes is concerned, the following general recommendations can be made for the future:

- Development and application of a unified terminology and methodology for MFA are needed.
- Accounting at a regional level to identify the relevance of the following processes:
  (i) MFA of production and distribution processes (industry and trade) to get information about inputs into and out from the technosphere,
  (ii) MFA of waste management processes (e.g. recycling plants, mining facilities, forest production, waste-water treatment plants, disposal facilities) to assess their impacts on the environment.
- Periodic actualisation of the data recorded (to provide time series) to assess the improvement of technical measures and policy instruments.
- Dynamic modelling to identify the key variables to be accounted for and gathering of reliable primary data as input for modelling purposes. One of the problems here may be the expenditure to provide a comprehensive reliable data base.

Focus Group Report:

Towards a General Framework for MFA III

Moderation and protocol: Gjalt Huppes

Participants: Arnulf Schönbauer, Nettie Gorter, Hein Mannaerts, Jeroen Guinée (notes), Wim Blom, Carsten Lassen

MFA, Material Flow Analysis, is one of a number of methods for chain analysis, applicable for different forms of chain management, all aiming to ultimately support sustainable development. The framework developed is valid for MFA in general, comprising SFA, Substance Flow Analysis, as one specific form of MFA. The framework of the other main method for chain analysis, LCA, with which MFA may slightly overlap, is similar. The framework for LCA is currently being specified in ISO 14 040.

MFA is a form of systems analysis, a system being defined externally in terms of its relations to its surroundings and internally in its structure with subsystems, basic entities and the relations between them. The object of analysis, that is the "thing" about which one wants to make statements, is part of the system. Systems analysis, and hence MFA, can be performed at very different levels of complexity, ranging from bookkeeping, hardly using any modelling assumptions at all, through simple modelling, using linear relations based on assumedly constant coefficients, to complex modelling in terms of multilayered feedback mechanisms constituting the autopoiesis mechanisms of the system. The level of system complexity chosen is quite directly related to the type of model used in MFA which, in turn, is quite directly related to the goal of the study.

How may these and many other choices in specific MFAs be made in a consistent way? It seems that working within a framework guiding such choices is a main option for arriving at consistency and transparency. Also, such a framework may help specify the limitations of the set-up chosen for a particular study. Such a framework is being developed here in a first version. It structures MFA in four phases, with only the first two of these worked out in some detail. Only main choices which have to be made are indicated, not stating how they should preferably be made. In due time, a more strict relation could be specified between goal and intended application on the one hand, and the appropriate set-up of the specific MFA on the other.

The framework chosen is a simple one, distinguishing three, or four, logically related parts in MFA. These are:

1	**Goal & Scope Definition**	(alternatively: Goal & System Definition)
2	**Inventory & Modelling**	(alternatively: Inventory Analysis)
3	**Interpretation**	
--		
4	**Application.**	

Applications may be seen as distinct from MFA itself, with MFA contributing to one or more applications. Alternatively, applications may be seen as an independent part of MFA, as will be the case where the aim is application is an interpretative one. The intended applications are reflected in the goal definition.

1 Goal and scope definition

In the goal and scope definition at least the following items are to be specified. The intended applications result in the formulation of:

- **goal** of the study

The scope choices relate to:

- **system** and possibly subsystems to be analysed
- **object** of analysis
- **basic entities** from which the system is built
- **flows** taken into consideration
- **depth** of study

The **goal of the study** may be general or specific. Very general goals are, e.g., development of MFA methods, general inquiries into the physical metabolism of society, or setting a framework for more specific studies. Examples of more specific goals are the dynamics in the flows and accumulations of a certain substance in some region, using SFA, or supporting the development of policies to direct material flows in an environmentally sound direction, e.g., to control the flows of a certain hazardous substance in a region. Goal and possible application are closely linked.

The **system** to be analysed is to be specified in relation to the three standard subsystems the world is divided into. These are:

- **technosphere**, that is the socio-economic system, comprising the physical economy
- **biosphere**, that is the biotic and related abiotic surroundings, including water, air and soil
- **lithosphere**, that is the immobile substrate in which processes take place on a geologic time scale

Additional definition: **biosphere + lithosphere = environment**.

The boundaries between these standard subsystems are not self-evident.

Advice: An explicit choice on the boundaries between technosphere, biosphere and lithosphere is needed in virtually all studies.

In many situations, the system is analysed at several levels, by distinguishing subsystems within it. Seen from the subsystem in which the object of analysis resides, there then are upstream and downstream processes. Upstream processes, in some contexts, may constitute the rucksack or hinterland parts of the central system. Downstream processes, related to the products and waste flows leaving the central system, may constitute the garbage bag of the system.

Advice: Instead of starting such an analysis at the subsystem level of, e.g. a region, it is preferred for reasons of transparency to first specify the full system taken into account and then specify the subsystems distinguished.

The **object of analysis** defines what exactly is the "thing being studied" about which statements are to be made. MFA is quite broad in the options here, which may range from a substance surveyed in its global or regional flows, to all mass flows in a sector, or to the global energy flows of a consumption type in a given region. The object of analysis may coincide with the system level chosen, but this is not necessary. If one studies the flows of a substance in a region, object of analysis and system level coincide. If one studies the global mass flows related to the consumption in a certain city, then the world is the system, with the city consumption being the object of analysis, and the city possibly being a subsystem. As there is a wide variety in MFA in this respect, only some aspects of the choice of object of analysis can sensibly be specified. These aspects are:

- the **location** of the object
- the **time** period considered for the object
- the **type** of object chosen.

The latter may be defined as the full region, a sector, total consumption, a life style or even a specific consumption. This is not an exhaustive listing but a minimum indication of different choices to be specified. If the object of analysis is related to a function, an overlap with LCA may result, depending on the other choices in the goal and scope definition. See also Udo de Haes in this volume.

The **basic entities** from which the system is built relate to "what the flows flow between". These entities may be installations, economic processes, firms, sectors, etc. Information on basic entities may be aggregated into larger units, like information on the flows of firms being aggregated into the flows of sectors. The other way around is not possible, as desaggregation requires extra knowledge. This choice is very much related to the entities on which data is available, see below under bookkeeping. In a software context, basic entities and aggregations thereof often are referred to as ‘nodes’.

The **flows** between basic entities may be specified at several levels of aggregation, e.g. as individual products or as more general product categories. Also, at a certain level of aggregation, they may be specified in different units, see the following non-exhaustive list. Some combinations are also possible, e.g. all organic materials in the human food flow, excluding the packaging.

Flow types in the economy	Possible units:
total of all products/wastes	[kg] [m3] [MJ] [$]
grouped products(inc materials) and/or wastes	[kg] [m3] [MJ] [$]
product (inc materials) and/or waste	[kg] [m3] [MJ] [$] [piece]
grouped compounds	[kg] [m3] [MJ]
compound	[kg] [m3] [MJ] [Mol]
grouped chemical elements	[kg]
chemical elements	[kg]

In the socio-economic system, specific products or wastes will usually be the basis on which data on flows are gathered. Such flows may be specified at a more disaggregated level, as (grouped) compounds or elements, or they may be aggregated into larger entities. Based on product/waste flows and their composition, all flow types mentioned can be derived in principle. In many cases, data on products are recorded in money units which, on the basis of the composition of the flow, may be converted into physical units as required in MFA.

In the environment system, flows will usually be specified in terms of (grouped) compounds and elements. Higher order flow types, like rivers or organisms, might be distinguished, similar to products in the economy. The basic entities between which flows occur would have to be specified first, as e.g. organisms might be basic entities in a study on the global carbon metabolism.

Depth of study

A more social-procedural aspect in MFA is part of the scope definition, that is the amount of time which can be spent on the study. This, to a large extent, determines how much detail and reliability can be reached and how much effort can be put in constructing convincing aggregations and generalisations.

2 Inventory & Modelling

The system and subsystems as defined in general terms in the goal and scope definition, are to be specified in the inventory analysis. Two types of knowledge are required, related to bookkeeping and to modelling.

Basically **bookkeeping** is concerned with data gathering on the flows from and to the basic entities, specifying these in the flow types desired. These entities and flows will have to be gathered somehow. Much data gathering currently taking place is related to economic considerations. In economics, not necessarily related to MFA, the basic entities on which data is gathered include

- governmental organisations (public households, I)
- firms (private households, II)
- families (private households, III)
- countries (imports and exports)

The flows specified in economics include

- goods and services
- incomes,
- taxes and subsidies

In economic bookkeeping, the units in which the flows are specified are usually related to these latter three flow types, with specifications in physical and functional units and in money terms. In MFA bookkeeping, such a clear basis for data gathering does not exist. Hence, in many instances, the basic data desired are lacking. Then other data, which are available, are used to estimate the desired data, based on some model or modelling assumptions. The basic entities relevant in MFA differ widely, covering at least the economic ones, like households (I, II, III), sectors, and countries, but also desaggregating these, as in installations and aggregating them differently, like regions larger than countries. Depending on the goal, the flows need to be specified also at a physical level, as total mass or in terms of mass or energy of compounds and elements, see above.

Whatever the goals in specific MFAs, it seems wise in primary data gathering, for bookkeeping purposes, to stick to the most disaggregated data gathering activities available, that is consumer surveys, production data, and import and export statistics, combined with standardised ways of reporting the physical composition of each flow. Such data may later be aggregated without much work, while desaggregation always requires new data gathering.

Advice: For international studies and for comparisons between countries it is necessary to have access to data in the same categories. Currently, two basic classifications are widely recognised internationally, PRODCOM for production statistics and ISIC for trade statistics. However, the basic categories in these are not the same. A translation is possible, but is not easy at a physical level. Also, when data on the composition of product/waste flows is gathered, these categories are often lumped into broader product categories. In different countries this is now being done differently. International coordination is highly desirable in establishing the flow types and basic entities for general MFA-relevant bookkeeping activities.

In many types of MFA, the object of analysis does not coincide with the system analysed. An example is the consumption in a region as the object, with the world as the system where effects of (changing) this consumption are taken into account. Then the effects the object has on this broader defined system is to be specified. In such more complex systems, the **problem of allocation** will occur. Allocation deals with how to separate the effects caused by the object analysed from all other human activities having the same type of effects. Essentially, one wants to know which effects are caused by the object, be it steel industry production in the Ruhr area, public transport in a city in Austria, or agricultural production in the world. The processes related to an activity in some area are not self-evident from the data: has the electricity imported into the Ruhr area been produced by an average mix of electricity in Europe, or North-western Europe, or by the marginal technique for electricity production in North-western Europe induced by the demand from the Ruhr area steel production? Of course several other options exist. Such questions cannot be answered by bookkeeping alone, they need some form of allocation, modelled or not. In SFA similar problems may arise when making an origins or destination analysis for some specific flow.

Advice: When establishing the effects which the object studied has on other subsystems, the way the allocation problem has been solved is to be indicated.

The modelling is concerned with the predictive use of MFA. A number of model types may be distinguished, each requiring their specific information on the causalities operant in the system studied. These main model types are the following.

1. mass balancing of the bookkeeping system, as a most simple kind of modelling
2. linear models (based on I/O-coefficients for, e.g., one year, "black boxes")
3. extrapolations based on time series
4. steady state, linear comparative-static equilibrium models (based on I/O-coefficients for one year)
5. steady state, comparative-static equilibrium models, based on knowledge on the behaviour of the entities and of larger units (I/O-coefficients then are variable, based on insight into the black boxes)
6. dynamic models, also based on knowledge of the behaviour of the basic entities and of larger units (I/O-coefficients here are variable as well, based on insight into the black boxes).

More simple models, like those based primarily on fixed input-output coefficients, lead to very different results as compared to models with more complex causal mechanisms. Of course, more complex models are hard to come by in a systematic way.

Example: Imagine that a major user of steel would stop buying steel from an oxysteel plant and would purchase from an electrosteel plant instead. The oxysteel process requires far more inputs, especially iron ore and coal, than the electrosteel process, with scrap as a main input. All data on current flows are available. Two models are used to indicate the effects of the shift in purchasing, both taking it as an exogenous change. In the first model type, the data on inputs and outputs are transformed into a fixed coefficients input-output model. Depending a bit on the choice of balancing items a substantial change in material flows will occur. However, in the second model type, where economic supply and demand functions are used as feedback mechanisms, a different outcome will result. The initial price changes induced by the decision of our steel buyer, that is lower prices for iron ore and coal and higher prices for scrap, would lead to shifts elsewhere in the economy from electrosteel to oxysteel, dampening the initial effect substantially. With very high elasticities of supply, the net effect resulting might be near zero. As may be expected, the choice of model is quite decisive on the results of predictions, even when both models start from the same data.

The models based on constant coefficients, e.g. in comparative static modelling, are most apt for indicating direction and relative magnitude of the effects of measures, in the short term, when these coefficients may remain more or less constant. The same holds for trend analysis, as a slightly more refined type of coefficient based analysis. If more long term effects of developments or policies are to be assessed, the main causalities operant in the long term should be incorporated in the models, or at least a sensitivity analysis incorporating basic mechanisms, like technological development and substitution mechanisms, are to be included.

It is interesting to note that scientists coming from chemical engineering see physical causality as the prime moving force, with "economic constraints" on them, while those coming into chain analysis from economics tend to see human behavioural variables as the moving force, with "physical constraints". Of course, both types of causalities are relevant in socio-economic systems; it is their combined effects which are to be assessed.

Advice: For assessing long term future developments and long term effects of measures and policies, more advanced models than those based on fixed input-output coefficients should be looked for, or at least fixed coefficient models should be applied in a careful way, e.g., reflecting basic demand or supply mechanisms.

3 Interpretation

No systematic discussion on the interpretation has been held in the focus group session. The two remarks made are stated here.

- The interpretation contains an assessment of the **validity and reliability** of the results of the inventory analysis.
- The interpretation can take two starting points, either the results of **bookkeeping**, or the results of **modelling**, related to two broad types of goals.

The first goal is the interpretation of society‘s relation to the environment as described historically by the **bookkeeping**. Such descriptions may go in very general terms like the trend and current position in "appropriation by societies of the net (or gross) primary production", in physical terms, which, next, can quite convincingly be related to grand effects like diminishing biodiversity. Also, measures countering this trend can well be imagined, like intensifying existing agriculture, not using biofuel except on the basis of wastes, protecting nature areas, etc.

The second starts at **modelling results** arrived at in MFA inventory analysis. As the quantified modelling required will tend to be more specialised, the interpretation will refer to more specific subjects, and from there to more specific kinds of measures. This is not necessary. Energy scenario analysis, working with broad causal models, has been developed in many places. The use of such models need not lie in their direct link to measures but in creating a background for thinking about measures.

Focus Group Report:

Relationship between MFA and Other Tools

Moderation and protocol: Helias A. Udo de Haes

Participants: Magnus Bengtsson, Anna Bjorklund, Helena Dahlbo, Avtar Jasser, Artti Juutinen, Niels Jungbluth, Jake McLaren, Ilmo Maenpaa, Yuichi Moriguchi, Carsten Nathani, Greg A. Norris, Richard Obernosterer, Stefan Speck, Knut Sörenson Andre Viergever, Andreas Windsberger, Nicoline Wrisberg

1 Inventory of tools for chain analysis

A distinction was made between analytical tools and policy instruments for chain management, see figure 1. Both, analytical tools and policy instruments, should take account of social preferences or life styles. The group started with an overview of analytical tools, relevant for analysing chains. This inventory resulted in 10 different analytical approaches. These were compared with respect to the following four items (see table 1):

- whether the approach represents a family of tools/is a tool in itself/or is an analytical element of one or more tools
- whether an approach has its core in the financial or physical economy or in the environment
- whether an approach addresses a single process or small part of the chain, or in principle addresses the whole chain in the socio-economic system
- the object of analysis.

Five families of tools were indentified: Material Flow Accounting (MFA); Life cycle approaches, with Life Cycle Assessment (LCA) as a specific tool; Input-Output approaches, with the specific tools monetary IOA, extended IOA and physical IOA; Environmental Impact Assessment (EIA); and Risk Assessment (RA), with the specific distinction between RA for activities and RA for substances. The first three of these have their focus in the socio-economic system, with larger or smaller extensions into the environment system; the latter two have their focus in the environment. Company Ecobalance was identified as additional separate tool at a company level, supportive for the analysis of chains of companies.

In addition, a non-exhaustive inventory of different analytical elements was made, resulting in the following elements: mass balances, allocation of environmental burdens to economic processes, environmental dispersion, dose-effect relationships, characterization and weighting.

Note. In this contribution MFA is defined as a family of tools, comprising Bulk-MFA and SFA as specific tools. Another option may be to call the family "Environmental Accounting", with MFA and SFA as specific tools. Following this terminology MFA only would deal with total-mass or material flows and would not comprise SFA which deals with substances or groups of substances. Following this line it would be a point of discussion whether also IOA can be seen as a tool within "Environmental Accounting" family.

2 Compatibility of tools.

The compatibility of the above mentioned tools or tool families was discsussed. The analytical tools may be incompatible for three different reasons:

- the technical or mathematical aspects of two (or more) methodologies are incompatible; this means that between them no formalized integration or link is possible
- the aims of two (or more) tools are incompatible
- the development of the methodology or underlying data for two (or more) are not available.

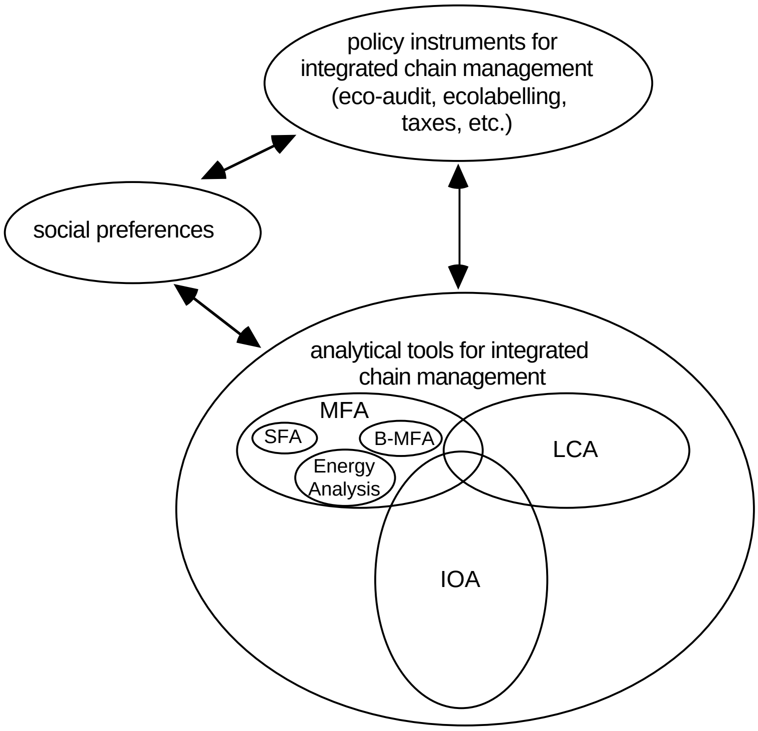


Figure 1: Policy instruments and analytical tools for integrated chain management, both dependent on social preferences

It was found that SFA is incompatible with both economic analysis (quantification of inter-process flows in monetary units) and with LCA. The reason for the incompatibility with monetary-economic analysis is that traces of substances have no economic value (or the economic value is 0), so these cannot be connected to monetary analysis. The incompatibility with LCA is due to a difference in the aim of the tools.

Furthermore LCA was found to be incompatible with EIA/RA and with IOA. The incompatibility with EIA/RA is a technical matter in the sense that localized problems cannot be accounted for in LCA. IOA and (traditional) LCA are not on the same level of detail. LCA concerns individual processes, while IOA addresses broad economic sectors. These two tools may well become compatible however, if the databases for IOA are adapted for LCA purposes (see below) and if they are becoming more detailed.

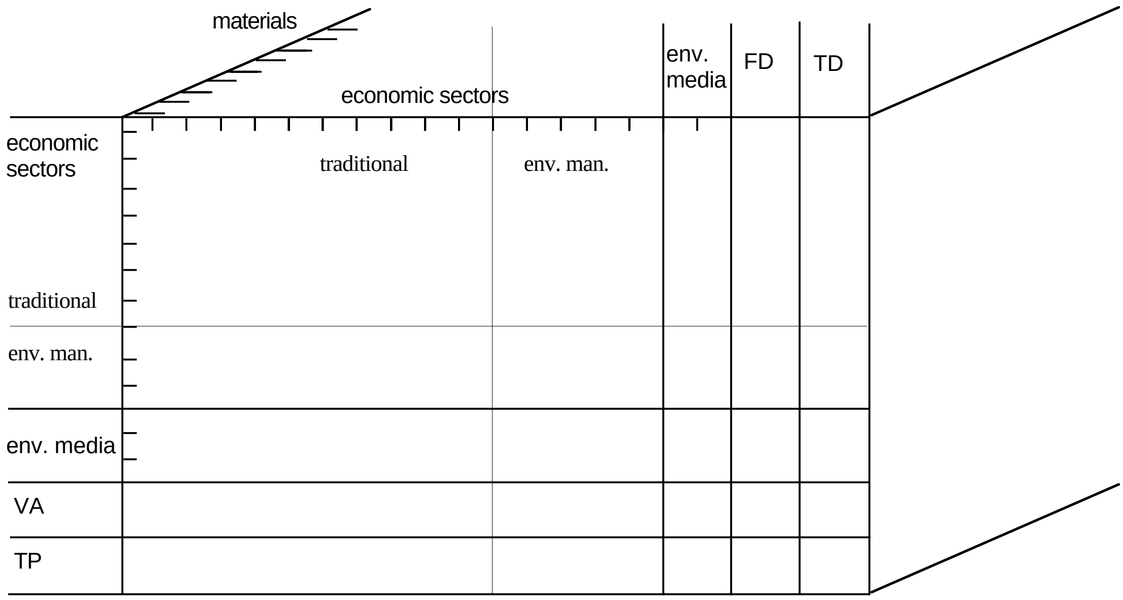
It should be noticed that if tools are incompatible, they may at the same time still complement each other.

3 General framework for chain analysis tools?

A general framework was presented by S. Speck for the different types of analytical tools for chain management, and further elaborated on basis of comments by Y. Moriguchi (see Figure 2). This will shortly be described here, not as a final result but instead as a start for further discussion and research. This framework is based on the Input-Output table. The core consists of the transactions between economic sectors in monetary terms. A distinction can be made between traditional economic sectors and economic sectors which specifically deal with environmental management. Furthermore, the sectors can be extended with environmental media (air, water, soil). In addition there is a row, representing the value added by the given sectors, and a sumrow, representing the total domestic production of the given sectors (with the environmental compartments as "pro memory"). And in addition there is a collumn, representing the final demands of the given sectors (households, capital formation and export), and a collumn representing the total demand for goods of the given sector.

The matrix can first of all be presented in monetary terms (the conventional IO-table). It may be extended towards a third dimension. This first of all includes a presentation in total-mass terms. Furthermore, in additional levels, more narrowly defined material flows can be presented, as is the object of MFA/SFA (materials or substances). In the levels of this third dimension the flows of materials and substances between economic sectors and also between these sectors and environmental media can be described.

Another way of presentation of the IO-table concerns the make-use analysis, which puts the sectors in the collumns and the commodities in the rows. The present figure is a step in that direction.



FD = final demand
TD = total demand
VA = total value added per sector
TP = total domestic product of economy
trad. sect. = traditional economic sectors
env. man. sect. = environmental management sectors
env. media = environmental media (air, water, soil)

Figure 2: Proposed comprehensive framework for chain analysis tools

It is proposed by the focus group that all tools can be seen as being derived from this format. Although a full reporting of data in terms of this format will remain problematic (see also below), the present framework may be helpful for analysing the positioning of and relationships between the different tools. It will also facilitate the linkage to financial-economic accounting procedures.

Note: A point for discussion is whether the framework also covers LCA, because of its function based object definition. Clearly, the concept, terminology and mathematical formulation of this general framework should be further elaborated.

4 The need for data bases

It was agreed that there is an apparent need for data bases at two distinctly different levels:

- input-output data bases at the level of economic sectors
- data bases at the level of single economic processes ("unit processes", i.e. the separate industrial processes of specific economic sectors)

In order to improve the usefulness of input-output data for chain analysis tools a further splitting up of the economic sectors is advisable; and also environmental data should be included in the matrix. In line with the discussion on Figure 2, the latter can be done in two different ways. Firstly, in an extended IOA satellite accounts can be developed, linking resource extraction and pollution data to the different sectors, per monetary or physical unit. Secondly, the transaction data themselves can be expressed in terms of more narrowly defined material flows (the third dimension in the figure).

For more detailed studies there is a need for databases at the level of separate economic processes. This need is particularly expressed for LCA purposes; here also a number of developments take place or have already taken place, including the definition of a common data format. But also MFA or SFA studies are in need of more detailed data, for instance to calculate the environmental burdens related to the rucksack problem. A better exchange between the two communities may lead to the development of data bases which are applicable to both families of tools and possibly others. A particular example concerns the fact that for LCA it is sufficient that a given unit process is characterized by its inputs and outputs for a reference magnitude of the process; for MFA purposes also the actual magnitude of the given process should be registered.

Database development is quite different in different parts of the world. Although still at a low level, the LCA-database situation at the level of separate economic processes is far better in the EU than in North America or Japan, which areas were for LCA purposes characterized as "data deserts". In contrast, I-O databases are far better in North-America and Japan, although still quite limited in their extension with emission factors. These remarks are made in response to the contribution of H. Friege from the Enquete Commission of the German Bundestag, who warned for the risk of creating "data cemetries", if data are gathered without clear purpose.

Table 1: Overview of analytical tool families, analytical tools and analytical elements for integrated chain management

name	hierarchy	scope of chain			object
		fin.	phys.	env.	
MFA	family		+	+/-	physical flows
- Bulk-MFA	tool		+		materials flows
- SFA	tool		+	+/-	substance flows
LC-approach	family		+	+	product-functions
- LCA	tool		+	+	product-functions
I-O approaches	family	+	+		mon./phys. flows
. monetary IOA	tool	+			mon. flows
. extended IOA	tool	+	+		mon./phys. flows
. physical IOA	tool		+		phys. flows
EIA	family			+	econ. activities
RA	family			+	activ./substances
- activities	tool			+	econ. activities
- substances	tool			+	substances
Company Ecobalance	tool		+		company/branch
Mass balance	element		+		mass/mat./subst.
Allocation	element		+		econ. processes
Env. dispersion	element			+	substances
Dose-response relationship	element			+	env. processes
Characterization	element			+	env. indicators
Weighting	element			+	env. indicators

Focus Group Report:

Policy Relevance of MFA I

Moderation and protocol: Viveka Palm

Participants: Frans Berkhout, Fredrik Burström, Hans Daxbeck, Roland Fehringer, Johan Hedbrant, Rodrigo Jiliberto, Sten Karlsson, Wolfgang Konrad, Nigel Lawson, Margareta Lundin, Jakob Maag, Anton Steurer, Thomas Wachter, Gia Wickbom, Keimpe Wieringa, Tim Young

How to make MFA appetising for a policy maker?

In order to make MFA a useful tool for the policy maker, it has to be stressed in what way MFA can be helpful. Today, this is not always well-known outside of the MFA community. In this procedure, it is also of interest to define which actors are in need of MFA, and for what purpose.

Two different uses were identified:

- MFA as a diagnosing instrument to help actual policy making
- MFA as an information tool creating public awareness of a certain problem or solution

As a diagnosing instrument MFA is most likely used by people with a certain knowledge in environmental policy, be it on state level or for a region or a company. The actors could be organisations, industries, sectoral ministries etc.

When MFA is used as an awareness raising tool, it is mostly to point out that the total consumption of some material is decisive in the total impact on the environment. The actors in this case would mainly be the public.

Integration

The keyword for the advantages of using MFA as a tool in environmental policy is ‘integration’. Below four aspects of such integration are listed.

1) MFA integrates the environmental problems with society and with the economic sectors, thus making it clear which actors are involved in the problems.
2) MFA is a mass balance approach, and this opens up possibilities to detect where there is accumulation or spreading of material in society, and also gives a good check on the quality of the available data. Thus, both production and stock can be accounted for, indicating missing links in the data material.
3) MFA is a means to integrate environmental problems with other socio-economically based models. Thus, it is possible to combine MFA with other tools, e.g. Input/Output models, to model technology changes and economic changes in close connection to material management.
4) MFA can show a nations environmental burden to other nations, thus a method for integrating the environmental problems across the borders, if care is taken to involve the environmental rucksack in the calculation.

Examples of environmental fields where MFA can be used

In the discussions an attempt was made to list some environmental problems for which MFA could be helpful in the use of diagnose or of awareness raising (see table 1).

For different substances it is often fairly straightforward to class which environmental problems are of interest. For materials this procedure is not equally transparent. From the list it appears that handling of bulk materials such as construction materials and fuels are of interest for climate change, toxification, resource depletion, waste management, land destruction and equity questions. Another ‘material’, namely food, is of interest for eutrophication.

Table 1: Some environmental problems where MFA can be of help.

Environmental problem	substance or material	awareness or diagnose
Climate change	fossil carbon, bulk materials	d/a
Ozone depletion	various substances	d
Eutrophication	nitrogen, food	d/a
Acidification	sulphur, nitrogen	d
Toxification	chemicals, metals, fuels	d
Resource depletion	resources: non-renewable and renewable	d/a
Land destruction through mining	fossil fuel and metal	d/a
Waste management	waste	d/a
Equity between generations	total consumption	a
Equity between regions	total consumption	d/a

Policy instruments and actors

Some differences between substance flow analysis and bulk flow analysis were discussed (figure 1). The distinctions found between the uses of substance flow analysis (SFA) and analysis of bulk flows are outlined in table 2. In the discussion it was noted that the use of SFA is already well established in several countries, where it is used by Environmental Protection Agencies (EPAs) to monitor and evaluate current regulations. The analysis of bulk flows has also been made, notably in Germany and Austria, but for information purposes rather than for regulation. It is expected that the use of bulk flow analysis will become more common in the future, perhaps used as indicator of sustainability and also in different scenario work together with other tools. Some work is conducted to see where recycling can become effective, including such materials as paper, glass and rubber. Also for that purpose material flow analysis will certainly be of interest, but then perhaps not so much for the EPAs as for different branches and sectoral ministries.

Table 2: Distinction of the use of substance flow analysis and bulk flow analysis.

	Substance flow	Bulk flow
Type of policy	Environmental control, "back end problem"	Resource, "front end problem"
Main MFA use	monitoring, evaluation	Scenario work together with other tools
Actors	EPA, Chemicals inspectorate	Public, branches, sectoral ministries
Main policy instruments	Bans, regulation	Information, taxes
Solutions	Substitution	Increased efficiency, recycling, changes in technology
State of use	Current	Prospective

MFA in policy

It was proposed that ‘policy relevance‘ could be investigated in the following way: There are four different elements to a policy where MFA can be of interest (Figure 2). In order to have a policy we first have to have a common view of what the situation is today, an ‘initial state’, defined by a problem definition. Then we need a more or less clearly defined final state, the desired goal of the policy. The third element is a description of the different ways to reach the desired goal, the policy instruments. The fourth element is to define some indicators, to be used to evaluate the result of the policy. If an MFA gives input to either of these elements, it is ‘policy relevant’

Analysing the MFAs being done today, it was proposed that many are mainly concerned with describing the initial state, what is sometimes referred to as book-keeping. This is of course an important contribution, as it often high-lights which problem areas are of concern, and what actors are involved. In the case of the SFAs, the environmental problem is often clearly defined, and the EPAs have sometimes already defined some 'desired goal' to be reached.

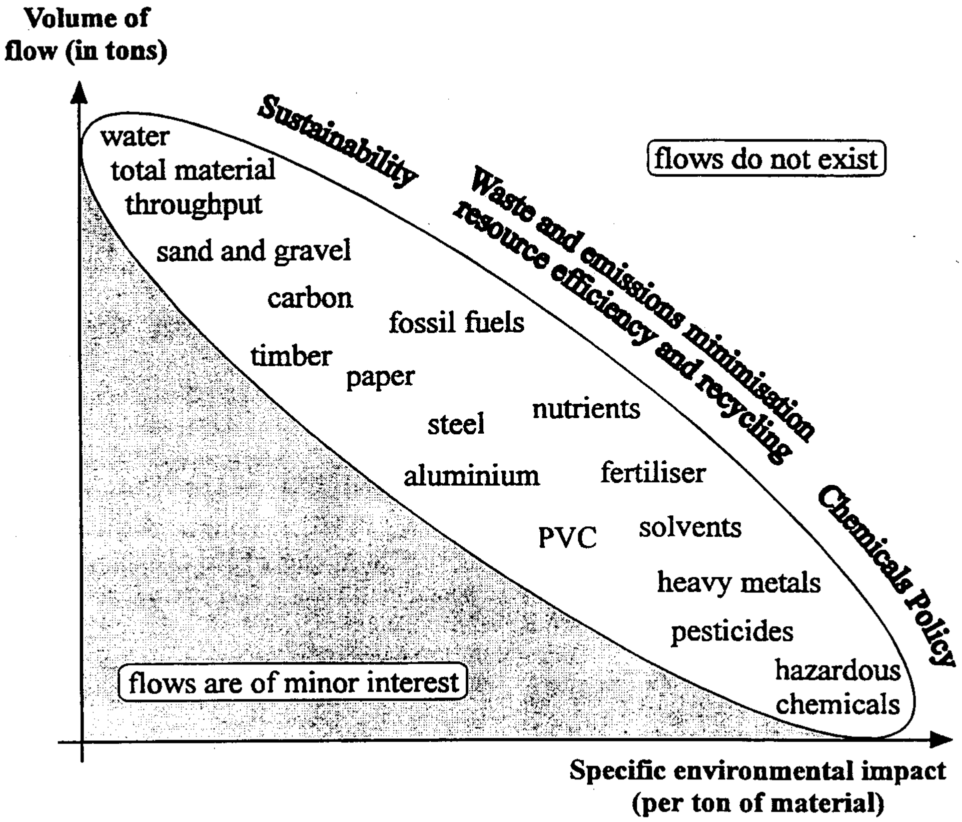


Figure 1: A stylised map of the materials of particular interest for accounting (Source: Steurer 1996)

1) initial state with problem definition

2) final state, the desired goal

3) different policies for reaching goal

4) formulation of indicators to follow up result

Figure 2: Four MFA-relevant elements of policy:

For the analysis of total consumption or of bulk flows however, these goals are not easily defined. Some attempts have been made, notably the 'decrease by a factor ten' proposed from the Wuppertal Institute, and the calculations of 'Environmental space' giving figures of a desired maximum resource consumption on a per capita basis as suggested by the Friends of the Earth.

Summary

It was concluded that MFA can be a good tool for policy formulation and that it can be used for two main purposes: either as a diagnosis instrument of direct help in policy making, or as an information tool that increases awareness about environmental problems linked to consumption. The use of substance flow analysis is already becoming a part of practise in some countries. It is expected that bulk flow analyses will become more common in the future, as a means to grasp how we can be efficient in our handling of resources.

Reference

STEURER, A. (1996); Material Flow Accounting and Analysis: Where to Go at a European Level. - In: Statistics Sweden (Eds): Third Meeting of the London Group on Natural Resource and Environmental Accounting, Stockholm, Sweden May 28-31, 1996, Proceedings Volume, pp. 217-221

Focus Group Report:

Policy Relevance of MFA II

Moderation: Stefan Bringezu

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Material flow analysis (MFA) has evolved during the last 150 years. National materials policies commenced after the Palin report in the USA in 1952 [Fischer-Kowalski, this volume]. The initial national materials policies focused on supply problems. On a firm level, MFA has been applied for decades as a tool to monitor and increase efficiency.

In the last three decades, environmental considerations have become a major incentive for materials policies. Only this MFA application will be discussed in more detail. Environmental MFA (further on called MFA) can be split into substance flow analysis (SFA) and (bulk) material flow analysis.

SFA examines the flows of substances which are known to be harmful to mankind or the natural environment, for example toxic heavy metals or nitrogen fertilizers. Bulk material flow analysis focuses on the material flows through the economy and the exchange flows between the environment and the ecnonomy which themselves are a priori not considered to be harmful, but which may pose environmental problems associated with their volume moved during extraction, processing, use and waste handling. Both types of analysis have a rather different status, which can be explained by the different environmental issues at stake and the different stage of development.

Because policies regarding harmful substances were among the first environmental policy areas, SFA has been applied for more than three decades. SFA has been widely accepted and has been applied as a tool for management of harmful substances in many countries. SFA has been used for the analysis of substance flows though the economy, the development of mitigation strategies and monitoring of policy impacts. As a consequence, SFA can be considered a mature method in a well establihed policy area.

MFA for bulk materials proves to be much more controversial. Its use is closely connected to specific environmental problems such as waste management and greenhouse gas emissions, as well as to the general problem of unsustainability. These problems emerged later on the political agenda. Some are even not yet acknowledged by everyone. Regarding greenhouse gas emissions and sustainability, policy goals and policy plans are still lacking in many countries. This is a major barrier and also a dilemma for the further use of MFA: without policies, there is no incentive for the use of MFA. And without MFA based information necessities and priorities for action will not become obvious. This problem may be expected to decrease within the next decades, when those policies will be established, and MFA will be proved to provide relevant support.

Apart from the lacking political framework, the method for bulk materials differs from SFA. In SFA, the analysis of a limited number of substance flows provides often sufficient insight into the specific problem. In bulk MFA, a broader range of materials and their interlinkages are analysed in a more comprehensive way. "Rucksacks" and "waste bins" must be considered. The results of both SFA and bulk MFA may be related to the various processes of the economy. If trends of materials productivity are studied, economic parameters must be coupled with mass flow parameters.

Currently, a major limitation of the broader use of MFA seems to be a lack of comparability. Based on different statistical classifications, using somewhat different system boudaries, and deriving different indicators (for different problems), not only a common framework of methodology is needed. In order to provide international comparable results a certain standardisation of the accounting will be indispensible.

Some researchers argue that products should be added as a third MFA research topic. Others state that product chain analysis is completely covered by LCA. Because materials are stored in products and waste materials are released from products, analysis of material flows implies often an analysis of product flows.

Who are the users ?

"Policy making" can be considered as the result of a process in which numerous groups participate. MFA users can be split into three major groups:

- decision makers in government and in industry;
- researchers;
- the general public / non-governmental organisations.

Each group can again be split into users on the international level, the national level, and the regional level. Each group has different data requirements regarding MFA. For decision making and for general information, aggregated data are most suited. As a consequence, a limited number of indicators with sufficient information should be provided by MFA. For implementation of decisions, for analysis of results, and for comparison of data and results, detailed information is required.

As a consequence, any account should be adjusted to the level of detail adequate to the (expected) user. A "tool box" of methods is required to apply MFA successfully not only for different problems but also for different users.

How can MFA be used ?

MFA can be used for:

- analysis of the relation between material and substance flows, and economic activities;
- development of environmental policy goals;
- implementation of strategies to achieve environmental goals;
- monitoring of trends and policy evaluation.

These different applications of MFA are not (yet) clear to (all) potential users. Again, its use seems more established for widely recognized environmental problems. Its use for sustainability policy making is still to be established.

Which requirements do the users have ?

The MFA requirements are similar to all accepted policy information tools:

- a simple and limited number of relevant indicators;
- a transparent method;
- reliable data;
- comparable results for different regions and different time periods.

What are the obstacles to use MFA for policy making, and how can these problems be solved ?

Obstacles	Solutions
Lack of comparability	Standardization This is a challenge especially for statistical offices
Lack of goals	Definition of new goals and/or redefinition of existing goals to improve communicability and attractiveness (e.g. such as Factor 10); search for operationalisation of generic goals like increased sustainability
Lack of "good" indicators	Use of MFA to derive sufficient precise indicators; indicators for sustainability should be based on the environmental space concept (e.g. such as materials productivity)

Conclusions

In order to improve the potentials of MFA for policy support it was concluded that

- there is a need for the comprehension and for the further development a "MFA toolbox"
- different questions require different tools to get the answer
- the most concise tool should be chosen that can provide the answer
- the international comparability of MFA results should be fostered by increased standardization
- policy goals for sustainability should be promoted whith respect to materials production and consumption
- MFA should be further used to derive plausible and relevant indicators of materials consumption and materials productivity

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