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ENVIRONMENT DIRECTORATE
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Working Group on Environmental Information and Outlooks

MATERIAL FLOWS AND RELATED INDICATORS
OECD APPROACH AND WORK PLAN FOR 2005-2006

This document relates to OECD work on resource and material flows and related indicators carried out as part of the OECD's environment programme and horizontal project on sustainable development.

It was prepared by the OECD Secretariat to guide OECD work to support the implementation of the OECD Council Recommendation on Material Flows and Resource Productivity, adopted in April 2004.

It describes the approach taken, specifies the scope and level of ambition of joint work within the OECD in this field, and describes events and time lines for delivering expected outputs in 2005 and 2006.

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NOTE BY THE SECRETARIAT

This document relates to OECD work on resource and material flows and related indicators carried out as part of the OECD's environment programme and horizontal project on sustainable development. It was prepared by the OECD Secretariat[1] to guide OECD work to support the implementation of the OECD Council Recommendation on Material Flows and Resource Productivity, adopted in April 2004.

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The document builds on:

- the results of the OECD Helsinki Workshop on Material Flows and Related Indicators (17-18 June 2004). The workshop gathered views from member countries of the OECD on the orientation and scope of joint work within the OECD on material flows and related measurement tools, identified the most promising areas for OECD work, and outlined next steps and expected outputs. (see Chair's summary ENV/EPOC/SE(2004)2);
- contributions received from member countries to the Helsinki workshop and to the Special Session on Material Flow Accounting of the WGEIO (October 2000);
- the results of a global survey of activities related to Material Flow Analysis carried out jointly with the European Environment Agency (EEA);
- comments received from country Delegates by the end of November 2004.

Further information on material flow related activities in OECD countries can be found in document ENV/EPOC/SE(2004)3/FINAL/ADD.

[1] The financial support of Japan is gratefully acknowledged.

MATERIAL FLOWS AND RELATED INDICATORS - OECD APPROACH AND WORK PLAN FOR 2005-2006

MATERIAL RESOURCE FLOWS AND RELATED INDICATORS OECD APPROACH AND WORK PROGRAMME

I. INTRODUCTION

1. Background and policy context[2]

1. Natural resources are a foundation of economic activity and human welfare. They provide raw materials, energy and other inputs, as well as environmental and social services. Their management and efficient use in the economy are key to economic growth and sustainable development and are part of the many cross-sectoral issues with which governments of OECD countries are increasingly confronted (Box 1).

2. Economic growth is generally accompanied by growing demand for raw materials, energy and other resources with consequences on market prices and on international trade flows of these resources. Concerns about shortages of stocks and the security of supply of natural resources and material have been recurrent throughout the past decades. Growing economic and trade integration has shifted policy issues from local and national levels to global levels. It has enlarged the size of markets, allowed greater specialisation in production, increased the role of multi-national enterprises and led to an overall increase in international flows in goods and materials. In recent years, resource consumption has again become an important issue as prices for energy and other material resources have risen amid growing demands from OECD and other countries, including China.

3. These developments have implications for the economic efficiency of natural resource and material use that has been gaining importance as a policy issue in many OECD countries and at business level, adding to concerns about the environmental effectiveness of resource use.

4. The environmental, economic and social consequences of the production and consumption of natural resources and of related economic activities extend far beyond the borders of OECD countries. From an environmental point of view, this has three types of consequences within and outside the OECD area:

- on the rate of extraction of non-renewable resources (e.g. fossil fuels, minerals, metal ores).
- on the extent of harvest of renewable resources (e.g. forest resources, agricultural resources, wild life, fresh water resources).
- on the intensity of the associated environmental burden (e.g. pollution, waste) and on the effects on environmental quality (e.g. air, water, soil, biodiversity), on the reproduction capacity and productivity of renewable resources, and on related environmental services.

2. Sustainable resource use

5. OECD countries are collectively among the biggest users of natural resources in the world. Because of the weight they have in global resource use, and because of the importance of the natural capital base of their economies, they have a particular responsibility and an important role to play in achieving more effective resource management and sustainable resource use.

[2] Based on earlier OECD work on natural resource management and on "*Sustainable development – Critical issues*" Chapter 10. Natural Resource Management, OECD, 2001

Box 1. Characteristics of natural resources and natural capital

Natural resources are part of natural capital and provide raw materials and environmental services that are necessary to develop human and social capital. They differ in their physical characteristics, abundance and value to different members of society and to different countries or regions.

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

- if depleted or degraded they cannot easily be replaced or restored;
- they form an integral part of larger ecosystems, and their depletion and degradation can lead to environmental degradation and reduced ecosystem services.

Natural resources fulfil three basic functions:

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

The value of natural resources depends both on:

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

6. The concept of sustainable resource use builds on an integrated approach to resource management. It encompasses aspects linked to the economic efficiency and environmental effectiveness of resource use at the various stages of the production and consumption chain, as well as related social aspects.

7. Effective resource management aims at optimising the net benefits from resource use by (i) ensuring adequate supplies of renewable and non-renewable resources to support economic growth and (ii) managing the environmental impacts associated with their extraction, processing and use. This is likely to contribute to increased resource productivity, i.e. greater output or value added per unit input of resources[3]. Resource productivity has an impact on the production process and on economic growth through impacts on capital stocks, and through impacts on costs in resource-intensive industries. These impacts can have positive effects as long as the costs of improved resource productivity do not exceed the cost reduction, and as long as efficiency gains outweigh increases in demand[4]. At the same time, improved resource productivity is also likely to be crucial in easing environmental constraints and delivering greater welfare[5].

8. Against this background, much progress has been made in developing policy frameworks for the sustainable management of natural resources that cut across policy areas and economic sectors. In many OECD countries, the issue of efficient management and sustainable use of natural resources has become part of national sustainable development strategies and/or environmental plans, and is supported with initiatives to promote waste prevention policies and integrated product policies.

9. Sustainable resource use has also moved up the international policy agenda. It is closely linked to Agenda 21, and to the plan of implementation of the 2002 Johannesburg World Summit on Sustainable Development that aims at promoting sustainable production and consumption.

[3] Resource productivity can be expressed with respect to (i) the physical or technical efficiency, i.e. the amount of material input required to produce a unit of output, material or service in the economy, or (ii) the economic efficiency, i.e. the money value of outputs relative to the money value of inputs, with a focus on resource cost minimisation.

[4] "*Measuring resource productivity: a background paper by David Pearce*", 2001, London

[5] "*Resource productivity: making more with less*", 2001, report by the Performance and Innovation Unit, Cabinet Office of the Prime Minister, United Kingdom

10. The Heads of State and Government of G8 countries addressed the issue of sustainable resource use and resource productivity, first in 2003, when they asked the OECD to work on material flows and resource productivity indicators, and second in 2004, when they agreed to launch a follow-up initiative "Reduce, Reuse and Recycle" (3R), upon proposal by Japan. (Box 2).

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

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

  This follows on the recommendations formulated in 1997 of the High Level Advisory Group on the Environment to the Secretary General of the OECD: "*... it is now time for the OECD to concentrate on increasing resource productivity with the same effectiveness it applied to labour productivity. This should be done not just for environmental reasons, but also for economic and social reasons*"[6]

12. The Council of the OECD has adopted several legal texts of relevance to sustainable resource use and resource productivity and concerning actions that Member countries agreed to carry out in the framework of the Organisation. Among these are decisions on transboundary movements of waste and recommendations on the management of waste, and on material flows and resource productivity.

13. The European Union, as part of its 6th Environmental Action Programme (6 EAP), is developing a thematic strategy on the sustainable use of natural resources for "*ensuring that the consumption of resources and their associated impacts do not exceed the carrying capacity of the environment, and breaking the linkages between economic growth and resource use*".[7] It is to be complemented with a strategy on the prevention and recycling of waste and with integrated product policies (IPP) aiming at improving the environmental performance of products through their entire life-cycle.

Box 2. G8 summit references to material resource flows and resource productivity issues

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

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

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

[6] "*Guiding the Transition to Sustainable Development: A Critical Role for the OECD*", Report of the High-Level Advisory Group on the Environment to the Secretary-General of the OECD, November 1997, Paris.

[7] Communication from the Commission to the Council and the European Parliament -Towards a thematic strategy on the sustainable use of natural resources COM(2003) 572 final.

3. Natural resource information for decision making

14. Putting in place effective natural resource management policies and optimising the net benefits from resource use within the context of economic development, while maintaining non-commercial environmental services and preventing resource degradation is not an easy task. It is complicated by a number of factors including inter-temporal trade-offs, spatial and distributive aspects, interactions between different resources, as well as uncertainties about future demand and supply, and about the environmental impacts of their exploitation and use. It requires a good understanding of the role of natural resources in the economy and of the implications of economic development for resource use and resource productivity. It is therefore essential that these policies are based on appropriate information on:

- Stocks, flows and depletion of commercial resources;
- Technologies, recycling and substitution;
- Physical properties, values and demands for environmental services provided by natural resources, and links between resource exploitation and use, and these services[8].

15. Such information can be obtained from various statistical sources, but its quality and relevance for natural resource and materials management need to be further reviewed and improved. Information is available on most commercial resources and their values. Information also exists on physical stocks and flows of selected individual resources and on certain parts of the process chains (e.g. energy resources, forest resources, freshwater resources), and related indicators are in current use in most OECD countries.

16. Information is however insufficient to give an integrated view of how different resources and materials (e.g. minerals, metals, energy, timber, water) flow through the economy (from their extraction or import to their processing, consumption, recycling and disposal). Gaps remain in particular as regards material resources other than timber, water or energy (e.g. minerals, metals), flows of secondary raw materials (recycled materials) and overall resource use in the economy, as well as in the coverage of international resource flows. Little is also known about links between natural resource exploitation and ecosystems, the values of non-commercial outputs, and the long-term environmental and economic impacts of natural resource degradation.

17. These information shortfalls have implications for the quality of policy debates on the management and use of natural resources and materials in the economy. Hence, better and reliable information about resource and material flows within national economies, as well as among countries and different parts of the world, is needed. This is fundamental to understand the role of natural resources in the economy and to monitor the economic and environmental effectiveness with which resources are used.

18. OECD countries' governments therefore decided to step up co-operation to improve their knowledge about material resource flows and resource productivity, notably by developing common measurement systems and indicators, and adopted an OECD Council Recommendation to this effect (April 2004, Box 3). This is yet another step in the development of environmental indicators that the OECD and its members pioneered as of the 1990s, and that has helped to inform decision making in many countries. It follows on earlier commitments to develop better information to integrate more fully environmental and economic decision making.

[8] At the meeting of the OECD Council at Ministerial level in 2001, ministers further emphasised that "The market prices of natural resources must reflect the full environmental and social costs and benefits of economic activity, to take better account of non-market values and long-term impacts. Progress requires improving the knowledge base through research on environmental thresholds and non-market values, making markets better serve conservation goals, and reducing the net costs of waste flows."

Box 3. Recommendation of the OECD Council on Material Flows and Resource Productivity

Endorsed by Environment Ministers on 20 April 2004
Adopted by the Council on 21 April 2004

THE COUNCIL,

Having regard to Article 5 b) of the Convention on the Organisation for Economic Co-operation and Development of 14th December 1960;

Having regard to the Recommendation of the Council of 8th May 1979 on Reporting on the State of the Environment [C(79)114)];

Having regard to the Recommendation of the Council of 31st January 1991 on Environmental Indicators and Information [C(90)165/FINAL];

Having regard to the Recommendation of the Council of 20th February 1996 on Implementing Pollutant Release and Transfer Registers [C(96)41/FINAL] amended on 28th May 2003 [C(2003)87];

Having regard to the Recommendation of the Council of 3rd April 1998 on Environmental Information [C(98)67/FINAL];

Having regard to the Communiqué of the OECD Council meeting at Ministerial level of 17th May 2001 which stated that "that OECD countries bear a special responsibility for leadership on sustainable development worldwide, historically and because of the weight they continue to have in the global economy and environment" and which asked the OECD to "continue to assist governments by: developing agreed indicators that measure progress across all three dimensions of sustainable development, including decoupling of economic growth from environmental degradation";

Having regard to the OECD's Environmental Strategy for the First Decade of the 21st Century endorsed by MCM in May 2001;

Having taken note of international work on Integrated Environmental and Economic Accounting (commonly referred to as SEEA);

Considering the need for better information designed to integrate more fully environmental and economic decision-making;

Convinced of the need for intensified efforts by OECD member countries to establish and use indicators of progress concerning the implementation of national and subnational policies on the environment, eco-efficiency and sustainable development; and to systematically compare achieved results with relevant objectives of environmental policies and, where appropriate, related international commitments;

Taking into account the close co-operation on environmental matters between OECD and other international organisations;

On the proposal of the Environment Policy Committee (EPOC):

I. Recommends that member countries:

1. Take steps to improve information on material flows, including its quality and relevance for environmental management, in particular:
   - develop methodologies to enhance knowledge of material flows within and among countries;
   - consolidate and improve data collection concerning material flows within and among countries;
   - develop tools to measure resource productivity and economy-wide material flows, including appropriate estimation methods, accounts and indicators;

2. Further develop and use indicators to better integrate environmental and economic decision-making, and to measure environmental performance with respect to the sustainability of material resource use;

3. Promote the development and use of material flow analysis and derived indicators at macro and micro levels;

4. Link environmental and economic related information through work on material flows, stocks and flows of natural resources, environmental expenditure, and macro-economic aspects of environmental policies;

5. Co-operate to develop common methodologies and measurement systems of material flows, with emphasis on areas in which comparable and practicable indicators can be defined, drawing on work already done at national and at international level.

II. Instructs the Environmental Policy Committee:

1. To support and facilitate member countries' efforts to improve information on material flows and related indicators, including through exchange of information on national and international innovative experiences;

2. To continue efforts to improve methods and indicators for the assessment of the efficiency of material resource use in important areas;

3. To develop a guidance document to assist member countries in implementing and using common material flow accounts;

4. To carry out these tasks in co-operation with other appropriate OECD bodies and other international organisations to prevent duplication and reduce costs;

5. To report to the Council on progress achieved by member countries in implementing this Recommendation, within three years of its adoption.

II. MEASURING MATERIAL FLOWS AND RESOURCE PRODUCTIVITY

1. Measurement tools based on material flow analysis

19. Among the potentially useful tools to measure material flows and resource productivity are material flow studies or Material Flow Analysis (MFA). MFA refers to the monitoring and/or analysis of physical flows of materials through the process chains. It is generally based on methodically organised accounts in physical units (usually in tonnes) comprising the extraction, production, transformation, consumption, recycling and disposal of different types of materials*. Compared to other measurement tools MFA has the potential to provide a more holistic and integrated view of resource flows through the economy and enables the derivation of economy-wide material flow indicators, including new indicators reflecting resource productivity or resource use efficiency that could parallel those describing labour productivity.

In the context of MFA, the term "materials" is often used in a broad sense. It can cover materials or substances – and sometimes products –, as well as underlying renewable and non-renewable resources, and the residuals arising from their extraction, production and use (such as waste or pollutant emissions to air, land water).

20. MF accounts are an integral part of environmental accounting and of the physical flow accounts family as described in the System of integrated Environmental and Economic Accounting** (SEEA). They are closely related to other types of natural resource accounts (NRA) and to NAMEAs (National Accounts Matrix including Environmental Accounts).

***The SEEA offers the following categories of accounts: flow accounts of non-produced raw materials, product flow accounts, residual flow accounts, and asset (stock) accounts, as well as hybrid flow accounts comparing physical quantities to matching economic flows. It distinguishes four major types of resource flows: natural resources, ecosystem inputs, products and residuals.*

21. MFA includes a variety of approaches and measurement tools at different levels of ambition, detail and completeness. Among the different approaches and measurement tools are: economy-wide material flow accounts (EW-MFA) and material flow balances, physical input-output tables (PIOTs), substance flow analysis (SFA), as well as various types of indicators that can be derived from these tools.

22. Indicators derived from MFA help monitoring the use of resources in national economies and the associated environmental pressures. They can be used to complement indicators derived from natural resource accounts already in use (e.g. intensity of forest resource use, intensity of water resource use), and to measure environmental performance with respect to the eco-efficiency of human activities and to resource productivity. MF indicators are generally grouped into input, consumption and output indicators. Most of them can be derived from individual economy-wide MFA without the need to compile a complete material balance, and can be related to socio-economic indicators and to other environmental indicators to calculate intensity or efficiency ratios (Annex II).

23. All these approaches and tools have their merits and drawbacks depending on the purposes for which their results are to be used. Their suitability and relevance for a given purpose, depends on their analytical soundness and measurability (technical feasibility, data availability and quality).

Economy-wide material flow accounts and material flow balances

When applied at the macro-economic level, MFA monitors the total amounts of materials or groups of materials used in an economy (throughputs), including both direct flows (i.e. flows of materials entering the economic process) and indirect flows (i.e. flows of materials not entering the economic process, but associated to resource exploitation and of relevance from an environmental point of view). Economy-wide material flow accounts and balances enable the calculation of economy-wide MF indicators that can be related to macro-economic indicators if compiled in a coherent framework. Economy-wide MF indicators can be used to monitor overall decoupling between economic growth and resource use and overall developments in resource productivity.

Physical input-output tables PIOTs provide a more comprehensive description of material flows between the environment and economy as well as within the economy, distinguishing not only categories of materials but also branches of production. PIOTs can be used in decomposition analysis and in modelling, and when compiled in a coherent framework, can be related to monetary input-output tables (MIOTs) through the establishment of hybrid flow accounts. Information derived from PIOTs can be used to monitor developments in resource productivity at the meso and micro levels, and to support decision-making at these levels. The implementation of PIOTs is a labour-intensive task; hence efforts are being made to develop simplified PIOTS at a higher level of aggregation that could usefully complement economy-wide material flow accounts.

Substance flow analysis SFA generally focuses on selected substances or groups of substances and quantifies the pathways of these substances within a given system. The implementation of SFA is a labour-intensive task. Results from SFA can be related to specific environmental problems linked to the substances monitored. They are particularly useful to support decisions at the local or micro level.

2. Material flow related activities in OECD countries

2.1 State of work[9]

24. MFA is a rapidly developing field of research with increasing policy relevance. Over the past decade, much progress has been made in developing, refining and harmonising methodologies for various types of MFA. Work carried out has been covering different resource flows at different levels of detail for different entities and with different system boundaries. Among these are total material flow accounts and indicators promoted through joint research efforts by Austria, Germany, Japan, the Netherlands and the United States involving governmental and non-governmental institutions[10], and collaborative work in Europe carried out by Eurostat on methodologies for economy-wide material flows[11] and by the European Environment Agency and its Topic Centre on Waste and Material Flows. This is further supported with international work on Integrated Environmental and Economic Accounting (commonly referred to as SEEA)[12], and with OECD work on environmental indicators (terminology, framework, selection criteria, guidance for use)[13] and on environmental accounting and material flows[14].

25. Practical applications have also progressed, mainly in areas where the demand for information from MF accounting is clearly identified and linked to (i) specific policy questions such as the sustainability of natural resource management, the efficiency of material or product use, or the control of chemicals and hazardous substances; and/or (ii) associated indicator development. Most OECD countries that have developed a national set of environmental or sustainable development indicators include in their set one or several indicators derived from MFA. In some countries, this has led to a move towards integrating MFA work in the national system of official statistics.

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9 For further details and related country sheets see document ENV/EPOC/SE(2004)3/FINAL/Add.

10 *The weight of nations: Material outflows from industrial economies*, Matthews, Emily, C. Amann, S. Bringezu, M. Fischer-Kowalski, W. Hüttler, R. Kleijn, Y. Moriguchi, C. Ottke, E. Rodenburg, D. Rogich, H. Schandl, H. Schütz, E. van der Voet, H. Weisz , WRI, Washington D.C., 2000
Resource Flows: The Material Basis of Industrial Economies ; Adriaanse, Albert, S. Bringezu, A. Hammond, Y. Moriguchi, E. Rodenburg, D. Rogich, and H. Schuetz,(1997), WRI, Washington D.C., 1997.

11 *Economy-wide material flow accounts and derived indicators – A methodological guide*, Eurostat, 2000

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

13 *OECD Environmental Indicators – Development, Measurement and Use*, OECD reference paper

14 *Special Session on Material Flow Accounting: Papers and Presentations*, WGEIO, OECD, 2003

26. To date almost all OECD countries carry out some activities on resource and material flows and related indicators, even though the status of such work, its characteristics and scope, purpose and policy use vary considerably across countries.

2.2 Short and medium-term prospects

27. Recent experience in OECD countries concerning material flow accounting and related indicators, together with earlier experience in developing and using environmental accounts and indicators, provides a good basis for developing material flow and resource productivity indicators to measure progress towards sustainable use of resources at OECD level.

28. It is however important to recognise that countries are at a variety of stages in developing and using MFA. Despite significant advances, conceptual approaches and methodologies applied to MFA still vary among countries and institutions, and merit additional clarification and convergence.

29. It has also to be recognised that, though many countries and international organisations have included MF indicators in their sets of environmental or sustainable development indicators, the actual use of MF information in policy making is still limited, especially at the national level. Hence little feedback has been received on the policy relevance of such information This is due among others to the fact that most MF work completed to date has shed light on the supply side (academic research, methodological and statistical work, development of MF accounts and derived indicators) and that international discussions about best practices have long been limited to the expert and research community.

30. The potential of MFA as a policy making tool is thus not sufficiently known and the meaning of various MF indicators is not always well understood by non-experts. Also, aggregated economy wide MF indicators have long suffered from a lack of credibility, with debates focusing more on their analytical soundness and statistical quality than on the measured values and their significance. This has created a gap between the supply of MF information and the perceived usefulness of this information for decision making.

Improving the quantitative knowledge base

Further conceptual and methodological work is needed in particular to agree upon a consistent terminology building on a common language and understanding of concepts and to define common harmonised system boundaries that should parallel those of economic accounts.

Specific areas in which work has to be moved forward include:

- the measurement of output flows (in particular solid waste) and flows of secondary (recycled) materials;
- the measurement of indirect flows (domestic and trade related);
- the definition and measurement of consumption indicators;
- the development of common conversion factors and coefficients;
- links with economic accounts, with monetary and physical input-output tables;
- links with environmental pressures and impacts;

There is also a need for:

- harmonised guidance on how to select, define and calculate MF indicators and for further refinements in definition and meaning of some important MF indicators.
- guidance on how to optimise related statistical work and enhance international comparability, i.e. ensure that the data necessary to calculate the values of the relevant indicators are of sufficient quality and can be obtained at a reasonable cost.

Improving the analytical knowledge base

Whereas natural resource accounts and indicators have individually proven their value in policy formulation, the use of combined sets of indicators or economy-wide indicators on natural resource and material flows in the overall policy debate needs to be further strengthened and the potential of MFA as a policy tool needs to be better known.

Further analytical work is needed to review the policy relevance of individual and sets of MF indicators, to improve the interpretability of MF indicators and to provide harmonised guidance on how to best use and interpret such indicators. This is crucial if MF indicators are to be turned into a useful decision making tool, in particular in the case of economy-wide indicators.

Developing an overall standard framework for MFA

To be useful and give all the insights needed, the different types of MFA need to be appropriately positioned within a broader architecture of accounts and indicators:

- Links with other indicators derived from natural and other resource accounts (e.g. water; forest, land, energy) or describing specific environmental issues and decoupling levels are important, as are links with other environmental accounts (energy, water and waste accounts in particular) and information tools (e.g. Pollutant Release and Transfer Registers, air emission inventories, waste statistics). These links and related synergies need to be better understood. They could be used to enhance the policy-relevance and interpretability of MF indicators, to relate MF indicators to environmental pressures and impacts, and detect shifts in environmental pressures from materials use between environmental media (air, land, water) or economic activity sectors.
- Links with national accounts and their aggregates are especially important to provide an integrated information system. They could be used to enhance the relevance of MF information for economic and trade policies. Among other links that merit greater attention are those between trends in material flows (domestic, international) and trends in market prices of certain materials or groups of materials.

III. OECD WORK ON MATERIAL FLOWS AND RELATED INDICATORS

31. OECD work on material flows and resource productivity is part of (i) the OECD environment programme and the work on environmental indicators steered by the Working Group on Environmental Information and Outlooks (WGEIO) and (ii) of the OECD's Horizontal Project on Sustainable Development that will address "Sustainable resource use including material flow accounting, decoupling and resource productivity" and is steered by the Annual Meeting of Sustainable Development Experts (AMSDE).

32. It will support environmental peer reviews steered by the Working Party on Environmental Performance (WPEP), and has close connections to work on waste prevention and recycling, and to the project on sustainable materials management (SMM) steered by the Working Group on Waste Prevention and Recycling (WGWPR).

1. Aim and purpose

33. OECD work on MF is to improve the quantitative and analytical knowledge base about natural resource and material flows within and among countries, so as to better understand the importance of material resources in member countries' economies and to inform related policy debates.

34. It is expected to help addressing some of the current gaps and shortfalls in MF information, to contribute to achieve greater convergence of already existing initiatives in OECD countries and to facilitate wider dissemination and uptake of existing experience and guidance. It will also help to further broaden the geographic scope of MF work and to expand it to other interested OECD countries so as to support the sharing of lessons and related international work.

35. The results are further expected to support the OECD's policy analysis and evaluation work, and in particular i) the measurement of environmental performance with respect to the efficiency of material resource use and the implementation of related policies – eco-efficiency, resource productivity, sustainable materials management, waste prevention –, and ii) the monitoring of decoupling of environmental pressures from economic growth. It is also expected to support the implementation of the OECD Environmental Strategy by improving information for decision making, and will support countries' efforts to measure progress in implementing national and sub-national environmental policies.

2. The foundations

36. The work builds on the foundations laid down by earlier OECD work on environmental accounting and environmental indicators, and on sustainable development, on OECD work on MF carried out since 2000, and on experience so far with MFA in individual member countries and other international fora.

2.1 OECD work on environmental accounting and environmental indicators

37. The OECD has long standing experience with environmental accounting and environmental indicators[15] and with the development of common approaches and concepts. It has been promoting the development of environmental accounting systems to better integrate economic and environmental information and assess the sustainability of resource use, and the calculation of derived indicators included in the OECD sets of environmental indicators.

38. Recent efforts have been focusing on areas where policy relevant information remains scarce or of insufficient quality and that have gained interest at national and international level. This includes continued data work on environmental protection expenditure and work on material flows and related indicators by the OECD Environment Directorate; and conceptual and methodological work on accounting frameworks for sustainable development by the OECD Statistics Directorate. It is complemented with related work on monetary input-output tables by the OECD Directorate on Science, Technology and Industry and the Statistics Directorate.

2.2 OECD work on sustainable development

39. The OECD has been working on sustainable development since 1998 following a recommendation by the High-Level Advisory Group on the Environment to the OECD Secretary General[16] and subsequent mandates from OECD Ministers in 1998 and 2001. Ministers recognised sustainable

[15] Joint work within the OECD has been instrumental in developing international environmental indicators using harmonised concepts and definitions, and promoting the use of a common approach to environmental indicators in OECD countries and beyond. See "OECD Environmental Indicators – Development, Measurement and Use, OECD Reference paper.

16 . *Guiding the Transition to Sustainable Development: A Critical Role for the OECD*. "that the OECD should become the leading international organisation analysing how best to harmonise economic, environmental and social policies, …."

development as an overarching goal of OECD governments and the Organisation and emphasised OECD countries' special responsibility for leadership on sustainable development worldwide. The work was designed to help Member countries address fundamental sustainable development issues by making the concept of sustainable development operational for public policies and moving beyond a sectoral approach to a more integrated approach. It also involves the development of appropriate tools to monitor progress towards sustainable development.

40. Between 1998 and 2001, OECD work concentrated on better understanding the significance of sustainable development for public policies and on examining the main policy challenges of relevance to sustainable development that OECD countries face as a group. It further reviewed the challenges for the measurement of progress and made proposals on how to identify and develop appropriate indicators and measurement frameworks.

41. Between 2001 and 2004, the links between the three pillars of sustainable development were further examined with emphasis on policy reform and implementation and on the analytical and scientific understanding in the area of sustainable development. The work focused on (i) indicators that measure progress across all three dimensions of sustainable development, including decoupling indicators, and their use in peer reviews; (ii) obstacles to reducing environmentally harmful subsidies and to the further use of environmentally related taxes; (iii) social aspects of sustainable development; and (iv) economic, environmental and social policy coherence and integration.

42. In 2005 and 2006, the OECD will continue to provide a forum for substantive policy dialogue on sustainable development and related cross-cutting issues, among which sustainable resource use, including material flow accounting, decoupling and resource productivity.

2.3 OECD work on material flows so far

43. Work on material flows was initiated in 1999 under the OECD Working Group on Environmental Information and Outlooks (WGEIO) following a joint proposal by the United States and Japan. The aim was to provide a forum for taking stock of progress made with material flow accounting at national and international level and for exchanging experience on how to best use information derived from material flow accounts to support decision making and policy development. The demand for such OECD work was further reinforced by requests from Heads of State and Government of G8 countries (Evian, June 2003, G8 Action Plan on Science and Technology for Sustainable Development) (Box 2).

44. Work so far has been supported by a sequence of events, including:

- An OECD seminar on material flow accounting (MFA), held under the auspices of the Working Group on Environmental Information and Outlooks (WGEIO) in October 2000, back to back with a seminar on waste material flows and resource efficiency held under the auspices of the Working Group on Waste Prevention and Recycling (WGWPR).
- An International Expert Meeting on Material Flow Accounts and Resource Productivity organised and hosted by the Ministry of the Environment of Japan (Tokyo, November 2003).
- The meeting of the OECD Environment Policy Committee at Ministerial level, where OECD Environment Ministers and the OECD Council adopted a Recommendation on Material Flows and Resource Productivity (Paris, April 2004)
- An OECD workshop on material flows and related indicators, hosted by the Ministry of Environment of Finland, and held under the auspices of the OECD Working Group on Environmental Information and Outlooks (WGEIO) in co-operation with the OECD Working Group on Waste Prevention and Recycling (WGWPR) (Helsinki, June 2004).

3. Further OECD work on material flows[17]

45. In 2005 and 2006, the OECD will work with its members and international partners to establish a common knowledge base on material resource flows and resource productivity. Attention will be given to both the "supply side" (how MF accounts and related indicators can be constructed) and the "demand side" (how MF indicators can be interpreted and used). It will:

- Provide guidance on how to best construct material flow accounts and indicators in a coherent framework that countries can easily implement and further adapt to their own needs.
- Provide practical indicators that measure the sustainability of material resource use with emphasis on the economic efficiency and environmental effectiveness with which these resources are used.
- Provide guidance on how to best interpret and use material flow and resource productivity indicators.
- Offer examples of good practices that countries may wish to draw upon.

This is to be further supported with policy work on sustainable resource use steered by the Annual Meeting of Experts on Sustainable Development (AMSDE).

3.1 General approach and working boundaries

46. In line with earlier OECD work on environmental accounting and environmental indicators, work on material resource flows and resource productivity will be concrete, user-oriented and pragmatic in its ambitions to capture major aspects of environment/economy interactions. It will concentrate on areas in which practical indicators are needed and can be defined to assess the economic efficiency and environmental effectiveness of natural resource and material use[18].

47. The work will proceed by adopting a modular approach distinguishing:

- core work within the OECD, i.e. work in areas where progress can best be obtained:

  (i) through joint efforts in the OECD; and
  (ii) by OECD countries as a group using a commonly agreed upon framework and terminology.

  Priority will be given to carrying out work in areas where results can be obtained over the next two years, and to launching work in areas where progress requires longer term efforts, and that could proceed in parallel possibly in co-operation with other international partners.

- additional and/or more detailed work in areas where progress can best be achieved through specific national efforts done on a voluntary basis, through case studies carried out in collaboration by member countries sharing common interests or through co-operation with other international partners.

3.2 Overall scope and level of aggregation

48. Core work within the OECD will concentrate on the national and macro-economic level and on the compilation of simple accounts that allow the derivation of selected economy-wide indicators (core and key indicators) and the calculation of related aggregates for the OECD as a whole and for OECD regions.

[17] The proposals for further work described here derive from the results of the OECD workshop on Material Flows and Related Indicators (Helsinki, 17-18 June 2004) and from subsequent discussions in the Working Group on Environmental Information and Outlooks.

[18] Other important aspects of sustainability, such as social sustainability, are not addressed here.

Priority will be given to (i) the measurement of direct flows[19] with a systematic coverage of transboundary and trade related flows, and (ii) the further development of methodologies for measuring hidden flows[20] – unused domestic extraction and indirect flows associated with imports.

49. This is to be complemented with a breakdown by major economic activity sectors and by material groups to increase policy relevance, ease interpretation, and facilitate the establishment of links with economic indicators and information systems.

- Priority will first be given to the measurement of high volume flows and work will concentrate on main material groups (e.g. ferrous metals, non-ferrous metals, construction minerals, wood biomass, fish biomass).
- This will be complemented, as and when appropriate, with information on low volume flows raising specific environmental concerns, such as those with a high specific toxicity. In this context, the usefulness of other monitoring and assessment tools, such as Pollutant Release and Transfer Registers or OECD work on chemicals and risk assessment, will be explored.

The appropriate level of detail of disaggregated information and the selection of grouped or individual material flows whose monitoring will be given special attention and be further specified in the course of 2005 in accordance with the purposes for which the results of MF studies and related indicators are to be used in OECD work.

50. Work on the separate measurement of flows of "secondary, i.e. recycled or reused" materials is seen as highly relevant, but requires longer term methodological and measurement work. Progress in this field will be pursued in parallel, but needs to be supported with additional work and case studies carried out on a voluntary basis by individual countries in a collaborative way. In this context, the linkages with waste statistics and waste accounts including NAMEAs will need to be explored.

51. The work is expected to cover the full material flow chain and will be structured within the PSR model to highlight the complementarities among various types of indicators and the way they can be related to environmental themes:

- Priority will be given to input indicators that are generally easier to measure and to consumption indicators that however require further refinement.
- Work on output indicators that attract increasing attention but require further refinement and methodological work, will proceed in parallel, even though it is not expected to show full results in the short term.

3.3 Improving the quantitative knowledge base: development of common material flow accounts and indicators

Core work

52. Core work will focus on supporting countries to prepare national material flow data under a common accounting framework as a basis for calculating a harmonised core set of practical MF indicators. Such indicators are expected to complement indicators derived from natural resource accounts already in use (e.g. water, forest, energy), and will help to move work on decoupling indicators forward by filling gaps in the field of natural resource and material use.

[19] Flows of materials physically entering the national economy for further use in production or consumption processes.

[20] Work on the measurement of hidden flows is seen as important in the OECD context, but requires longer term work to improve data availability and comparability. In the short term, core work will focus on methodological aspects and could benefit from additional and voluntary efforts by countries sharing common interests.

53. This will be accompanied with (i) further conceptual, methodological and analytical work to provide guidance to countries and achieve greater convergence of individual initiatives, and (ii) further exchange of experience on best practices concerning institutional arrangements and partnerships and ways to enhance co-operation and communication between the various actors involved and to improve the cost-effectiveness of MF work.

54. Work will build as much as possible on existing work and experience, be consistent with the System of integrated Environmental and Economic Accounting (SEEA) and be co-ordinated with ongoing and planned methodological work by Eurostat.

Expected outputs

55. Expected outputs include:

- the preparation of a guidance document on methodological and measurement issues related to the development of MF accounts and indicators. The guide will be constructed in a modular way to reflect several levels of ambition and completeness of accounts, including a didactic or instructive part with a set of simple economy-wide MF accounts to allow newcomers to join in. It will also include an overall standard framework for MFA that helps understanding the links among different types and levels of MF approaches and measurement tools and the different purposes for which they can be used.
- The selection and definition of MF indicators for use in OECD work, and the subsequent measurement of these indicators building on data already available in countries and from international sources.

Supporting events and mechanisms

56. The work will be supported with (i) an OECD workshop on material flow indicators and related measurement tools and a training session on material flow accounting by Eurostat to be held in May 2005 and (ii) mechanisms that facilitate technical exchange among experts (electronic discussion groups, clearinghouse).

57. It will be carried out in close co-operation with Eurostat, whose guide will serve as a starting point[21], and in consultation with the UNSD to ensure coherence with the SEEA. It will in particular benefit from inputs from the Eurostat Task Force on Material Flow Accounting.

Proposed additional and/or more detailed work

58. Additional technical guidance and exchange of experience would be welcome to support those countries that wish to establish more detailed, country-specific accounts and indicators (e.g. sector or substance specific) or to explore new areas of work (e.g. weighing MF information to reflect environmental impacts). Such work will require longer term efforts and should build as much as possible on work in progress in other international forums. The actual development of more detailed accounts and indicators and their application at sub-national level or micro-economic (enterprise) level is mainly the responsibility of individual countries, but could be supported with case studies and forum discussions and be steered and co-ordinated by the OECD.

[21] . *Economy-wide material flow accounts and derived indicators – A methodological guide*, Eurostat, 2000; *Integrated Environmental and Economic Accounting 2003- Handbook on national accounting*, United Nations, European Commission, IMF, OECD, World Bank, 2003

3.4 Improving the analytical knowledge base: use and interpretation of MF indicators

Core work

59. Core work will focus on providing harmonised guidance on how to best use and interpret MF indicators. It will address the extent to which methodological issues, data quality and country-specific factors affect the interpretation, policy relevance and international comparability of different MF indicators. It will further identify the type of additional information and analysis that is needed to explain driving forces behind indicator changes and to relate MF indicators to environmental pressures and impacts and to resource management issues (use of renewable versus non-renewable resources; use of materials versus existing reserves and available resources; resource productivity; links to prices, to resource rents, etc.).

60. It will be accompanied with further analytical work to review the policy relevance for different purposes, and to identify those issues and policy areas to which MF analysis and MF indicators can best contribute. Extra efforts are required to improve the relationship between the demand for and supply of MF information, promote the use of MF approaches at national level and make the potential of MFA as a policy tool better known. The sharing of good practices and successful applications of MFA, could support such efforts.

Expected outputs

61. Expected outputs include:

- the preparation of a guidance document on the interpretation and use of MF indicators, including examples of good practices and successful applications.
- the preparation of a brochure on MFA and related indicators to communicate about the usefulness of MFA.

Supporting events and mechanisms

62. The work will be supported with (i) an OECD workshop to be held in 2006 (Q2); and (ii) an updated survey of the use MF indicators and related measurement tools in OECD countries and beyond. It could also benefit from pilot studies testing a few important MF indicators for selected OECD countries so as to gain further insights.

3.5 International co-ordination and co-operation

The work is carried out by the OECD Environment Directorate. It will benefit from co-ordination and co-operation with member countries and with international partners within and outside the OECD:

- OECD: Statistics Directorate, Directorate for Science and Technology, Horizontal Project on Sustainable Development (AMSDE)
- European Union: European Commission (Eurostat, DG Environment), European Environment Agency and its Topic Centre on Waste and Material flows
- United Nations: UNSD, UNEP
- London Group on Environmental Accounting, Inter-Secretariat Working Group on Environment Statistics
- Non governmental institutions: e.g. World Resources Institute, Wuppertal Institut, Institute for Interdisciplinary Studies of Austrian Universities.

4. Overview of expected outputs and supporting events

4.1 Expected outputs

❶ Brochure on material flow analysis and related indicators

- to serve communication purposes by giving a bold vision of MFA and explaining in simple and accessible terms the potential uses of MFA and the links to policy concerns, information needs, etc.
- targeted at users of MF information including policy makers, business and the public

Timing: 2006 Q1

❷ Guidance document on methodological and measurement aspects

- to assist countries in implementing common MF accounts and indicators in a coherent framework as requested in the Council Recommendation
- to build on the Eurostat guide and on the SEEA
- to be constructed in a modular way; core to focus on the construction of simple accounts and of economy-wide indicators that can be derived from data available in a majority of OECD countries
- to include empirical examples from OECD countries and best practices
- to be adapted by countries to their own circumstances and policy needs

Timing: 2006 Q1

❸ Guidance document on the use and interpretation of MF indicators

- to assist countries in using common MF indicators as requested in the Council Recommendation
- to build on analytical work to help improve the interpretability of MF indicators and to provide harmonised guidance on how to best use and interpret such indicators
- to include: examples of good practices and successful applications; a review of policy relevance for different purposes; a review of major advantages/drawbacks of different indicators

Timing: 2006 Q3/Q4

❹ Measured MF indicators and improved information base on major MF variables for use in OECD work

- to complement other natural resource indicators included in the OECD Core Set
- to be selected and defined according to their policy relevance, analytical soundness and measurability
- to be compiled from existing national and international data sources

Timing: 2006 Q2-Q3 (practical steps to be further defined)

❺ Assessment of progress made by member countries

- to report about progress made in implementing the Recommendation within three years of its adoption (as requested in the Council Recommendation)

Timing: 2006 Q4 / 2007 Q1

4.2 Sequence of supporting events (2004-2006)

Date	Event	Purpose and topics	Outputs
2004			
June 17-18	**WGEIO workshop** (Helsinki, Finland)	Definition of scope and orientations of joint work within the OECD on material flows and related indicators	➡ Chair's conclusions (basis for OECD programme of work) (June 2004)
Sept/Oct	**Annual meeting of Sustainable Development Experts** (AMSDE)	Sustainable resource use	
October 13-15	**35th WGEIO meeting** (Paris, France)	Discussion of draft scoping paper Exchange of experience on "demands for MFA"	➡ Final scoping paper (Q1 2005)
November 8-9	**Eurostat TF-MFA**	Review of Eurostat methodological guide and identification of next steps; development of simplified MF accounts	➡ Draft amended methodological guide (basis for OECD guidance document) (Q1 2005)
2005			
February 9-10	**7th WGWPR meeting**	First discussion of OECD work on sustainable materials management	
May 23-24	**WGEIO workshop** (Berlin, Germany) back to back with Eurostat training session on MFA (25 May)	Standard framework for MFA and bold vision; review of methodological and measurement issues; selection criteria and definition of MF indicators; related guidance to countries	➡ Draft guidance document on methodological and measurement issues (Q3 2005) ➡ Draft brochure on MFA (Q3 2005)
Sept/Oct	**Annual meeting of Sustainable Development Experts** (AMSDE)	Sustainable resource use	
November 28-30	**WGWPR workshop** (Seoul, Korea)	Sustainable materials management	
November 30 - December 1	**36th WGEIO meeting** (Cancùn, Mexico)	Review of draft guidance document; of draft brochure Discussion of MF indicators for OECD use	➡ Final guidance document on methodological and measurement issues (Q1 2006) ➡ Final brochure (Q1 2006) ➡ Preliminary set of MF indicators for OECD use
2006			
2nd quarter	**WGEIO workshop** (location de be defined) (to be hosted by member country)	Interpretation and use of MF indicators; links with other accounting tools and indicators; best practices and successful applications; could cover SMM indicators Update of survey on MF activities in OECD countries (focus on indicators)	➡ Draft guidance on the interpretation and use of MF indicators (Q3 2006)
Sept/Oct	**Annual meeting of Sustainable Development Experts** (AMSDE)	Sustainable resource use	
4th quarter	**37th WGEIO meeting** (location to be defined)	Review of draft guidance document on interpretation and use of MF indicators; Review of draft report assessing progress with MFA and related indicators in OECD countries	➡ Final guidance document on interpretation and use of MF indicators (Q4 2006) ➡ Final progress report (Q4 2006/ Q1 2007)

ANNEX I. A brief history of Material Flow Studies

Material Flow studies or Material Flow Analysis (MFA) have long been carried out mainly by academics (universities, research institutes) building on concepts such as the industrial ecology or the industrial metabolism*, and using the methodological principles of mass balancing in line with the first law of thermodynamics (conservation of matter). From a conceptual point of view, they show similarities with concepts such as asset balances for environmental capital (e.g. genuine savings) or ecological footprints. The principles of statistical approaches towards material flow accounts and material balances date back to the 1970s[a].

Terms such as industrial metabolism[b] or societal metabolism[c] metaphorically suggest considering modern economies as living organisms whose dominance in, and impact on, a given eco-system can be indicated by the size and structure of its metabolic profile[d] *.

A distinction often found in MF studies is between material and substance flows, where substances tend to mean 'pure' chemical elements or compounds (e.g. heavy metals, chlorinated chemicals) and materials the actually observed flows of raw materials, products and residuals which are often, but not always, a mixture of various substances (e.g. fuels, water, timber, total material throughput). MF analysis can be applied to a wide range of economic, administrative or natural entities including whole economies, industries or establishments; nations, territories, cities; and catchment areas or eco-zones.

* This has been rooted in different scientific disciplines with historical traits relating to the report of the "President´s Materials Policy Commission" ("Paley report", 1952), the Princeton conference on "Man´s role in changing the environment" (Thomas, 1956), and articles published in the Scientific American Issues of September 1970 and September 1971 on substance flows and energetic metabolism. Pioneering work was performed by Wolman (1965) on the average metabolism of a city. The first analyses of material exchange between the US economy and the environment were carried out by Ayres and Kneese (1969).

The technique of mass balancing and flow accounting has been widely applied to materials of specific environmental importance, and has been used for the analysis of biogeochemical cycles and the analysis of natural ecosystems. Analysis of various individual substance flows has often been performed to monitor the risk of exposure to hazardous chemicals such as heavy metals.

The idea of economy-wide aggregated material flow accounts and balances, as opposed to single-material or substance accounts, has been applied first in the 1970s (Gofman et al 1974). Such accounts and the indicators derived from them provide an aggregate picture of the entire material and energy throughput of a society/economy. Economy-wide MFA was revitalised and put into statistical practice in the early 1990s as part of research projects in several OECD countries as a contribution to the debate about sustainability issues. A key development was the wide application of economy-wide MFA and material balances in Austria[e], Germany[f], Japan[g], the USA[h] and the Netherlands, and the joint publication of this work by the World Resources Institute (WRI).

At the same time, research has been advancing and standard concepts and methodologies have evolved. In 1996, a research network called "Coordination of Regional and National Material Flow Accounting for Environmental Sustainability" (ConAccount) was established by the Wuppertal Institute for Climate, Environment and Energy to provide a platform for information exchange on MFA among scientists and practitioners of MFA. ConAccount builds on close cooperation 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 project was initially funded by the European Commission (1996-1998) and is supported with regular meetings. Work on methodologies and frameworks for MFA has also been advanced thanks to work on Integrated Environmental and Economic Accounting (commonly referred to as SEEA)[i] and to collaborative work in Europe carried out by Eurostat on methodologies for economy-wide material flows[j].

In 2000-2001, an International Society for Industrial Ecology (ISIE) was created to promote the use of industrial ecology in research, education, policy, community development, and industrial practices, and to facilitate communication among scientists, engineers, policymakers and advocates who are interested in how environmental concerns and economic activities can be better integrated. MFA is among the key topics covered.

a] United Nations (1976): Draft guidelines for statistics on materials/energy balances - UN document E/CN.3/493.
b] Ayres, R.U. (1989): Industrial Metabolism. In: Ausubel, J.H. and H. Sladovich (eds.): Environment and technical change, Washington DC.
c] Fischer-Kowalski, M., Haberl H. (1993), Metabolism and Colonisation. Modes of Production and Physical Exchange between Societies and Nature, Wien.
d] Schandl, H. and Schulz, N. (2000): Using Material Flow Accounting to operationalise the concept of Society's Metabolism. A preliminary MFA for the UK 1937-1997. ISER Working Papers, Paper 2000-3, University of Essex
e] Steurer, A. (1992), Stoffstrombilanz Österreich 1988. Schriftenreihe Soziale Ökologie, Band 26. Wien.
f]. Schütz, H. and S. Bringezu (1993), Major Material Flows in Germany. Fresenius Env. Bull. 2: 443-448
g] Japanese Environmental Agency (1992), Quality of the Environment in Japan 1992. Tokyo
h] Rogich, D.G., et al (1992), Trends in Material Use: Implications for Sustainable Development
i] Integrated Environmental and Economic Accounting 2003- Handbook on national accounting, UN, EC, IMF, OECD, World Bank, 2003
j] Economy-wide material flow accounts and derived indicators – A methodological guide, Eurostat, 2000

ANNEX II. A description of main indicators derived from Material Flow Studies

Extract of "Economy-wide material flow accounts and derived indicators – A methodological guide", Eurostat, 2001

Input indicators

Direct Material Input (DMI) – measures the direct input of materials for use into the economy, i.e. all materials which are of economic value and are used in production and consumption activities; DMI equals domestic (used) extraction plus imports. DMI is not additive across countries. For example, for EU totals of DMI the intra-EU foreign trade flows must be netted out from the DMIs of Member States.

Total Material Input (TMI) – includes, in addition to DMI, also unused domestic extraction, i.e. materials that are moved by economic activities but that do not serve as input for production or consumption activities (mining overburden, etc.). Unused domestic extraction is sometimes termed 'domestic hidden flows'. TMI is not additive across countries.

Total Material Requirement (TMR) – includes, in addition to TMI, the (indirect) material flows that are associated to imports but that take place in other countries. It measures the total 'material base' of an economy. Adding indirect flows converts imports into their 'primary resource extraction equivalent'. TMR is not additive across countries. For example, for EU totals of TMR the intra-EU trade and the indirect flows associated to intra-EU trade must be netted out from the TMRs of Member States.

Domestic Total Material Requirement (domestic TMR) – includes domestic used and unused extraction, i.e. the total of material flows originating from the national territory. Domestic TMR equals TMI less imports. Domestic TMR is additive across countries.

Consumption indicators

Domestic material consumption (DMC) – measures the total amount of material directly used in an economy (i.e. excluding indirect flows). DMC is defined in the same way as other key physical indictors such as gross inland energy consumption. DMC equals DMI minus exports.

Total material consumption (TMC) – measures the total material use associated with domestic production and consumption activities, including indirect flows imported (see TMR) but less exports and associated indirect flows of exports. TMC equals TMR minus exports and their indirect flows.

Net Additions to Stock (NAS) – measures the 'physical growth of the economy', i.e. the quantity (weight) of new construction materials used in buildings and other infrastructure, and materials incorporated into new durable goods such as cars, industrial machinery, and household appliances. Materials are added to the economy's stock each year (gross additions), and old materials are removed from stock as buildings are demolished, and durable goods disposed of (removals). These decommissioned materials, if not recycled, are accounted for in DPO (see below).

Physical Trade Balance (PTB) – measures the physical trade surplus or deficit of an economy. PTB equals imports minus exports. Physical trade balances may also be defined for indirect flows associated to Imports and Exports.

Output indicators

Domestic Processed Output (DPO) - the total weight of materials, extracted from the domestic environment or imported, which have been *used in the domestic economy*, before flowing to the environment. These flows occur at the processing, manufacturing, use, and final disposal stages of the production-consumption chain. Included in DPO are emissions to air, industrial and household wastes deposited in landfills, material loads in wastewater and materials dispersed into the environment as a result of product use (dissipative flows). Recycled material flows in the economy (e.g. of metals, paper, glass) are not included in DPO. An uncertain fraction of some dissipative flows (manure, fertiliser) is 'recycled' by plant growth, but no attempt is made to estimate this fraction and subtract it from DPO.

Total Domestic Output (TDO) - the sum of DPO, and disposal of unused extraction. This indicator represents the total quantity of material outputs to the environment caused by economic activity.

Direct Material Output (DMO) - the sum of DPO, and exports. This indicator represents the total quantity of material leaving the economy after use either towards the environment or towards the rest of the world. DMO is not additive across countries.

Total material output (TMO) - measures the total of material that leaves the economy. TMO equals TDO plus exports. TMO is not additive across countries.