Project WP3c Cooperation with DG Environment
– Thematic Strategy on the
Sustainable Use of Resources –

Zero Study:

Resource Use in European Countries

An estimate of materials and waste streams in the Community, including imports and exports using the instrument of material flow analysis

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Legal notice

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Summary

Objective of this study is to support the development of a *Thematic Strategy for Sustainable Use and Management of Resources* through the provision of background information, in particular "an estimate of materials and waste streams in the Community, including imports and exports" (Article 8 a 6th EAP) using the method of material flow accounting. It further presents first ideas on how the resource use pattern of the EU can be assessed with regards to priority setting for possible policy measures.

By referring to the concept of Industrial Metabolism, *resources* are defined in a broad sense, embracing the source and sink function of the natural environment, i.e. the provision of raw materials and land, and the absorption of residual materials (waste and emissions). Environmental impacts are associated not only with the extraction, harvesting and catching of raw materials but also with the subsequent production, use and disposal of products and goods. It is the total of environmental impacts associated with the entire life cycle of raw materials which has to be considered.

Three generic "management rules" for the sustainable use and management of renewable and non-renewable natural resources are presented and discussed which have been formulated by several political institutions based on scientific literature:

1. The use of renewable resources should not exceed their renewal and/or regeneration rates.

2. The use of non-renewable resources should not exceed the rate at which substitutes are developed (should be limited to levels at which they can either be replaced by physically or functionally equivalent renewable resources or at which consumption can be offset by increasing the productivity of renewable or non-renewable resources).

3. Outputs of substances to the environment (pollution) should not exceed the assimilative capacity of environmental media ("absorption capacities").

However, the application of these general rules to the real material flow system of the EU – leading to some priorities for a future policy – is still very difficult due to limited knowledge and information on the causal linkages between single raw materials, their subsequent life cycle and the related environmental impacts. Only for the case of energy carriers have first findings of this cause-effect chain been elaborated on a sophisticated level of detail (i.e. CO_2 emissions arising from combustion of fossil energy carriers).

The limited knowledge on the cause-effect linkages and the unfeasibility of overcoming this information-gap in the mid to long-term lead to the precautionary rationale that a strategy aiming at the reduction of the resource flow volumes will also prevent environmental impacts. Accordingly, a final scientific assessment of the material flow volumes does not seem feasible yet and requires further analyses and research.

It is expected that in the context of the development of the Thematic Strategy, a political assessment and priority setting – based on discursively obtained normative criteria – is required before full scientific proof will be available on the complex interlinkages between resource and material flows on the one hand and associated environmental impacts on the other.

The material flow analyses (MFA) presented in this study provide first information on the volume, structure and interlinkages of European resource and material flows. Hence, they can provide some general system characteristics of the industrial metabolism. In the future, a more in-depth analysis may be undertaken on specific impacts and cause-effect relationships in order to further assess European resource use patterns.
The main findings and conclusions from the MFA conducted for the European Union and 13 Accession Countries can be summarised as follows:

1) *Relative but no absolute de-coupling – resource productivity increased:*

   Direct material use and total material requirements have been decoupling from economic growth in relative terms since they kept constant or only increased slightly over the last decades. The material input flows into the EU-15 economy – measured as Direct Material Input (DMI) - have been nearly constant since 1980, fluctuating at approximately 16.5 tonnes per capita annually. The DMI of the AC-13 – with data available since 1992 – has been slightly increasing throughout the nineties, to finally reach the level of some 11.5 tonnes per capita.
   Thereby, the resource productivity has been increasing. This implies that the market forces already favour resource efficient production which means that increased resource productivity is also relevant for reasons of competitiveness.

2) *Resource-use levels still seem unsustainably high:*

   However, in absolute terms, resource use still remains at unsustainable high levels with regard to both its volume and the structure. The lack of an absolute decline in the volume of direct material inputs and total material requirement implies that the environmental burden related to resource use is remaining constantly high. The material output flows (emissions, waste etc.) – responsible for the levels of known environmental impacts and subject to main environmental policies – are widely determined by the material input flows also due to the law of conservation of matter. About 40% of direct material input is balanced by the same amount of processed outputs to the environment in the form of air emissions, waste, waste water and dissipative losses. Whereas the number of “exit” points of material output flows are innumerably high, the number of “entry” points of material inputs is few and hence more manageable.
   The composition of the EU´s DMI and TMR is characterised by a dominant share of non-renewables (74% and 88%). The non-renewable share of DMI in Accession Countries is below the EU with some 60%.

3) *There are remarkable differences between countries*

   With around 50 tonnes per capita the level of EU’s TMR is comparable to that of Japan, lower than that in USA, and within a range of around 32 t/cap in Italy and almost 100 t/cap in Finland. Materials use in terms of DMI is on a significantly lower level in Accession Countries and has been slightly rising throughout the 1990ies. Accession Countries will face difficulty in curbing the growth in the use of resources while striving to reach EU levels of economic welfare. Resource productivity (GDP per tonne DMI) is lower in Accession Countries by a factor 5. It will require extraordinary efforts to achieve EU levels of resource productivity.

4) *Burden shifting*

   There is a significant shift in resource requirements from domestic sources towards the use of imports and thus a shift in environmental burden of resource use to other regions. Therefore, resource use is increasingly becoming a matter of international burden sharing. EU’s resource requirements are increasingly met through imports, particularly metals and industrial minerals. The indirect “hidden” flows associated with imports are showing an increasing trend. Similar trends apply to most Accession

Countries.

5) *Physical growth of EU economy*

   In the EU, a considerably high amount of around 60% of the annual direct material inputs increases the material stock of the economy (about 10 t/cap). At present, this physical growth is closely related to the growth of built-up areas and energy requirements for maintenance of buildings and infrastructures which also affect future capacity for renewable supply and resource regeneration. In future, generation of construction waste will increase.

6) *Little changes call for policy efforts*

   Aggregate MFA indicators (DMI, DMC, TMR) change very little over time – as is the case for energy aggregates. This implies that a change of the structural characteristics of EU's resource-use patterns would require long-term policies. The moderate changes seem to be closely linked to economic events (e.g. aftermath of second oil crisis early 1980ies, economic recession in 1993).
   For single countries, an absolute decline in resource and material use could be observed but has been related to specific policy influences, indicating that business as usual will not lead to absolute reductions. For example, the use of fossil fuels (in particular associated "hidden flows") has decreased significantly during the 1990ies, mainly due to a changed mix of energy carriers from coal towards oil and gas. Restructuring of Germany's energy sector significantly contributed to this development.

7) *Scientific assessment hardly possible – calls for precautionary principle and political/normative assessment*

   In the near future, it will not be scientifically possible to assess which environmental impacts of resource use are of prior importance, nor to determine the various specific impacts of major resource flows which are or may become especially relevant in the short or long term. This may justify application of the precautionary principle. Volume and composition of the resource requirements will have to change if the various environmental implications of resource use, material throughput and physical growth are to be diminished and the supply not only of energy but also of materials is to be provided on a more renewable basis.
   Therefore, priority setting for policy measures will probably require political/normative assessments, e.g. based on the "management rules" mentioned above.

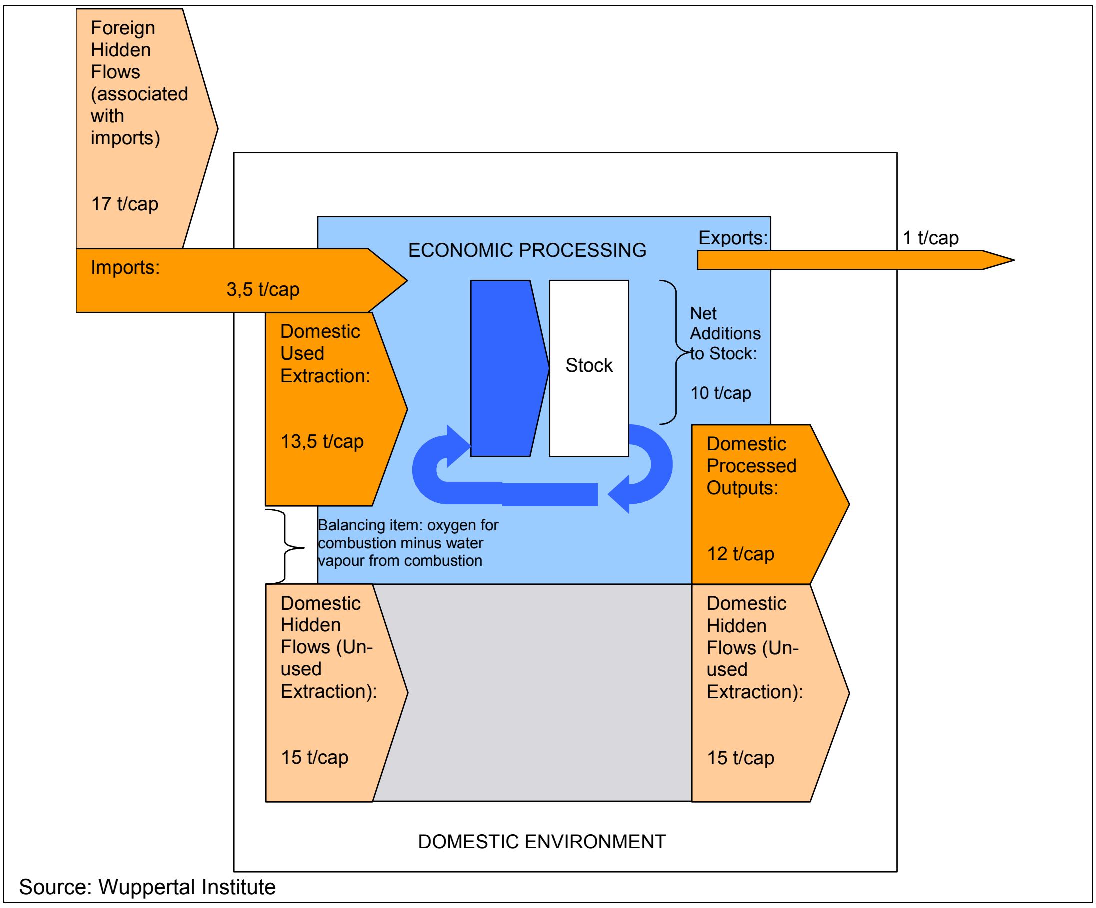

Figure 1-1: Estimated economy-wide material flows in the EU, on a per capita and year basis and for the second half of the 1990ies

1. Introduction and Objectives

The objectives of this study – derived from the 6th Environmental Action Programme – are two-fold. Firstly, it aims at the description of the resource use patterns of the European Union including imports and exports using the method of material flow accounting (MFA). Secondly, it will develop first ideas how to explain and assess the resource uses of the EU in order to support priority setting.

The Sixth Environmental Action Programme (6th EAP) identifies four priority areas, one of which being "natural resources and waste". Within this priority area the 6th EAP announces the development of a thematic strategy on the sustainable use and management of resources, including inter alia: (article 8, European Parliament and the European Council 2002):

(a) an estimate of materials and waste streams in the Community, including imports and exports, for example by using the instrument of material flow analysis;

(b) a review of the efficiency of policy measures and the impact of subsidies relating to natural resources and waste;

(c) establishment of goals and targets for resource efficiency and the diminished use of resources, decoupling the link between economic growth and negative environmental impacts;

(d) promotion of extraction and production methods and techniques to encourage eco-efficiency and the sustainable use of raw materials, energy, water and other resources;

(e) development and implementation of a broad range of instruments including research, technology transfer, market-based and economic instruments, programmes of best practice and indicators of resource efficiency;

In the course of the preparations of the thematic strategy, the Directorate General on the Environment (DG ENV) has explicitly asked the European Topic Centre on Waste and Material Flows (ETC/WMF) to provide help – particularly with (a). The terms of reference for this study were jointly developed and have been implemented into the ETC work programme 2002.

The instrument of Material Flow Analysis (MFA) and derived indicators provide information whether the overall resource throughput is rising or falling, and whether national economies are becoming more or less efficient in their use of resources. MFA constitutes a valuable starting point for further analyses and it has to be recognised that it is at the level of sub-accounts – the examination of specific materials flows, and categories of like flows – that MFA will have most relevance to detailed policy making (Matthews et al. 2000, p. 3).

The structure of the study follows the terms of references as agreed with DG ENV. Chapter 2 presents first ideas to identify criteria for the assessment and priority setting for a sustainable resource management. Chapter 3 introduces the methodology of material flow accounting (MFA) which has been applied for the data presentations in the following chapters. Chapter 4 provides an overview of the resource use trends of the EU. Resource use trends of the 13 EU Accession Countries are given in chapter 5. In chapter 6, a first interpretation and assessment of the EU resource use pattern is made based on

the reflections as developed in chapter 2. Conclusions and recommendations for the further process are given in chapter 7.
All data used in the study are made available in a comprehensive data annex (EXCEL workbooks).

2. Identifying Criteria for Priority Setting for Sustainable Resource Management

With regard to the development of a Thematic Strategy on the sustainable use of resources, the initial Commission's proposal to a 6th Environmental Action Programme identified the need to[1]:

"…establish a consistent analytical framework to identify criteria for setting priorities and undertake the necessary analysis and data collection in order to identify which resources are of most concern. The criteria will need to address issues such as whether the environmental damage associated with the use of a particular resource threatens to be long term and irreversible, whether current resource use depletes the capacities for future supply with renewable resources."

Although the final 6th EAP [2] does not contain this section anymore, it seems nevertheless necessary to identify criteria for a priority setting of natural resources which should be addressed by a Thematic Strategy. This chapter[3] presents first ideas towards such criteria.

Starting from a broad definition of natural resources considering the "source" as well as the "sink" functions of natural systems, it is argued that a resource management will probably have to address the entire human induced material flow system ("Industrial Metabolism"). Environmental impacts are associated not only with the extraction, harvesting and catching of raw materials but also with the subsequent production, use and disposal of products and goods. It is the total of environmental impacts associated with the entire life cycle of raw materials which has to be considered.

Some generic "management rules" for the use of renewable and non-renewable natural resources are presented which have been formulated by several political institutions based on scientific literature. However, the application of these general rules to the real material flow system of the EU – leading to some priorities for a future policy – is still very difficult due to limited knowledge and information on the causal linkages between single raw materials, their subsequent life cycle and the related environmental impacts. Only for the case of energy carriers have first findings of this cause-effect chain been elaborated on a sophisticated level of detail (i.e. CO_2 emissions arising from combustion of fossil energy carriers).

The limited knowledge on the cause-effect linkages and the unfeasibility of overcoming this information-gap in the mid to long-term lead to the precautionary rationale that a strategy aiming at the reduction of the resource flow volumes will also prevent environmental impacts. Accordingly, a final scientific assessment of the material flow volumes does not seem feasible yet and requires further analyses and research. It is expected that a political/normative assessment and priority setting – based on discursively

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[1] COMMISSION OF THE EUROPEAN COMMUNITIES (2001): 'Environment 2010: Our future, Our choice' – The Sixth Environment Action Programme, COM (2001) 31 final, Brussels, 24.1.2001, p. 51.

[2] Decision No 1600/2002/EC of the European Parliament and of the Council of 22 July 2002 laying down the Sixth Community Environment Action Programme, Official Journey of the European Communities L 242, Vol 45, 10 September 2002 (http://europa.eu.int/eur-lex/en/archive/2002/l_24220020910en.html)

[3] At a working meeting with the Commission in September 2002, it was decided that the assessment criteria to be developed should focus on the environmental dimension, i.e. the life-cycle-wide environmental impacts induced by the human use of natural resources. Economic and social criteria should also be considered with second priority.

obtained normative criteria – is required before full scientific proof will be available on the complex interlinkages between resource and material flows on the one hand and associated environmental impacts on the other.

2.1. Relating the use of natural resources to the size and composition of the "Industrial Metabolism"

There is no commonly used definition of 'natural resources'. It can range from a rather narrow one, considering only raw materials, to a very broad one encompassing all basic functions provided by natural eco-systems.

The broadest definition of "natural resources" encompasses all basic functions to humans provided by natural eco-systems (or the environment) (modified after SRU 1988):

1. source function (production of renewable and non-renewable resources, biomass etc.);

2. sink function (to absorb residual flows such as waste and pollutants);

3. cycling function (global material cycles, reproduction of biomass);

4. information function (gene pools, model or prototype for technical systems);

5. recreation function (e.g. for leisure time, aesthetics of nature).

The Commission of the European Community (CEC 2002) has put forward the following definition: "Resources can be defined as those parts of the earth's biological and mineral endowment from which society derives value". According to this, natural resources are classified into 5 categories reflecting their "functional areas of interest":

(1) Renewable resources that are non-extinguishable, such as wind and sunlight. Reservoirs such as oceans and air can also be seen as renewable (or replenishable), since these reservoirs are regenerated in time. On the other hand, if the use of these reservoirs outweighs the speed of regeneration, these resources become non-renewable in nature. For example, if oxygen take-up by human activities would outweigh the production of oxygen by green plants, depletion of oxygen would take place.

(2) Renewable resources that are extinguishable, i.e. all biological resources (including biodiversity) and vulnerable reservoirs (such as fertile soil, fresh water basins).

(3) Non-renewable resources that are non-extinguishable, such as metals and minerals. Although these resources cannot be destroyed, they become dispersed gradually, either by natural causes (leaching) or by human activities (mining and use). In principle, recovery is possible, but requires a lot of energy, particularly if dispersion in the environment has taken place (e.g. zinc from tires, which is dispersed on roads, is in principle recoverable but since its concentration in run-off water is very low this would require a lot of energy.)

(4) Non-renewable resources that are extinguishable, i.e. fossil fuels. These resources play a temporary role by definition: either the use will stop because of detrimental impacts or depletion or because better alternatives are found (e.g. flow resources and biomass).

(5) Space. It is obvious that space is required to produce all aforementioned resources: energy (e.g. solar and wind parks), agriculture and forestry (including the conservation of biodiversity). These functions have to be combined with all human activities that are related to the use of resources, e.g. housing, manufacturing and transportation. Space may therefore be considered as a key resource.

Obviously, environmental implications are not only associated with the extraction, harvesting and catching of raw materials but also with the subsequent production, use and disposal of products and goods. It is the total of environmental impacts associated with the entire life cycle of raw materials which will probably be considered in the frame of a resource management policy.

Also in this study the use of natural resources will be considered in the broader context of natural functions. This also requires a wide operational means to make resource use visible and approachable for policy.

Towards this end, it is proposed to relate to the concept of "industrial metabolism" re-introduced[4] by several authors since the beginning of the 1990ies (e.g. Ayres 1989, Baccini and Brunner 1991, Bringezu 1993; Fischer-Kowalski and Haberl 1993) and also used as a conceptual foundation for economy-wide material flow accounts (Eurostat 2001, p. 11).

The concept of "industrial metabolism" provides a comprehensive systems perspective of the interaction between environment and economy/society whereby the material flows between the anthroposphere and nature constitute the interface between human activities and environmental impacts.

Most changes of the environment are brought about by human-induced material flows. The "industrial metabolism" starts with the extraction of raw materials, comprises material and energy use for production and consumption, continues with recycling and ends up with final disposal. Material flows form the "bridge" between human activities on the one side and environmental impacts on the other side (Bringezu 2002). Therefore, for analytical purposes as well as for evaluation, we will address resource use from the perspective of the use in the whole of industry and society.
Quantity and quality of this "industrial metabolism" is subject to analysis and discussion on how to manage it in a sustainable way.

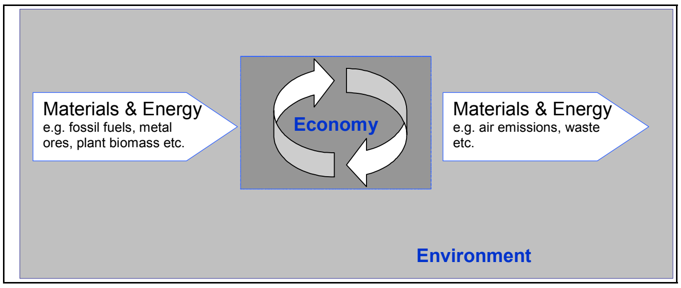

Figure 2-1: The Concept of Industrial Metabolism – 'What goes in must come out'

[4] For a science-historical review of the concept see Fischer-Kowalski (1998) and Fischer-Kowalski and Hüttler (1999).

2.2. Management rules

According to the complex matter, there is no unequivocal definition of the “sustainable use” of resources. Usually a common understanding can rather be found on resource use which can be assessed to be not sustainable. But even then the experts’ view may differ, depending on varying assumptions, different width and depth of perspectives, uncertainties and basic values. Therefore, working out what can be understood as “sustainable use of resources” cannot be “value free” and – beyond the individual level – will depend on the policy objectives.

The 6th EAP remains rather general in aiming at “…better resource efficiency and resource and waste management to bring about more sustainable production and consumption patterns, thereby decoupling the use of resources and the generation of waste from the rate of economic growth and aiming to ensure that the consumption of renewable and non-renewable resources does not exceed the carrying capacity of the environment” (Article 2, 6th EAP).

From the scientific debate on sustainable development three basic management rules have been evolving (Barbier 1989, Daly 1990, Pearce and Turner 1990, Meadows et al. 1992, Bringezu 2000). Those management rules were initially formulated from an economic viewpoint in order to secure the resource basis of a sustainable economy but were also formulated to specify the ecological dimension of sustainability.

1. The use of renewable resources should not exceed their renewal and/or regeneration rates.

2. The use of non-renewable resources should not exceed the rate at which substitutes are developed (should be limited to levels at which they can either be replaced by physically or functionally equivalent renewable resources or at which consumption can be offset by increasing the productivity of renewable or non-renewable resources).

3. Outputs of substances to the environment (pollution) should not exceed the assimilative capacity of environmental media (“absorption capacities”).

These “management rules” can also be found in various policy documents. For instance, the OECD Environmental Strategy agreed by Environment Ministers in OECD countries in 2001 adopts these rules as criteria for environmental sustainability and adds a fourth one on the avoidance of irreversibility (OECD 2001).

Based on these three basic management rules Bringezu (2002) proposed to operationalise the “carrying capacity” aspect by outlining a structure and size of the industrial metabolism of the European Union which can be continued on the long run without damaging the natural functions (Target Material Flow Balance). Most important criteria for such a target system for the European Union would be to secure the continuous supply and management of materials and energy in order to guarantee the resource basis for future economic activities without exceeding the carrying capacities of natural eco-systems. A first sketch providing a rough outline of the metabolic structure according to minimum requirements comprises three basic elements (modified after Bringezu 2000, p 24 ff.):

(1) material supply from natural resources will largely rely on sustainably cultivated biomass;

(2) The physical growth of the technosphere will come to an end and evolve towards a flow equilibrium of construction and deconstruction (i.e. Net

Additions to Stock = 0);

(3) The extraction of naturally non-renewable resources will be minimised (i.e. abiotic raw materials input will decline by some 90%). The use of these resources will largely depend on recycled matter.

2.3. Environmental impacts induced by material flows and their causal links

The concept of "Industrial Metabolism" teaches us that the materials exchange between anthroposphere and nature is the basic constituent of human induced environmental impacts. The "management rules" provide us with general guidelines to design the industrial metabolism whereby the material input flows rather relate to the "source" function and the material output flows to the "sink" or assimilation function of the environment.

However, with regards to "translating" these general findings into policy making based on clear priorities, at least two basic questions arise:

1) Which materials flows (inputs and outputs) and stocks are associated with which environmental impacts?

2) How are material inputs linked to material outputs? Or, which raw material or resource inputs will lead to which material outputs?

Scientific knowledge is still very limited and research is only at the very beginning of providing answers to these basic and complex questions.

ad 1) Material flows and their associated impacts

There is a huge variety of environmental impacts and there is no and will probably never be a unique theoretical concept that integrates all the various environmental impacts and provides unequivocal guidance to prioritisation. Types of environmental effects associated with material flows can be quite different, ranging from (eco)toxic effects (hazardous substances), over physico-chemical changes (acidification, global warming etc.), over nutritional effects (eutrophication) and mechanical destruction (e.g. by excavation) to structural effects (e.g. landscape changes, habitat disruption). Some environmental impacts are rather related to specific substances – other impacts are rather related to the volume of bulk material flows. Some environmental problems are well investigated and known – others are hardly investigated or might still remain undetected. So far, mainly material output flows have been investigated with regards to their substance specific impacts. Prominent examples are, for example, air emissions like CO_2, SO_x, NO_x etc. Assessing the overall impact of the different material flows and their interrelations is hampered by a high degree of uncertainty on the specific effects and their combinations, thus providing plausibility rather than evidence for applying the precautionary principle.

The "aggregated" impact associated to material flows is a function of the specific impact per unit and the volume as is illustrated in the following stylised map of selected material flows. Material flows in the ellipse may be regarded to have an aggregated environmental impact which is of similar importance, while this results from different specific effects. Although no aggregate measure of environmental impact is available yet, one may assume that the overall environmental impact of a small flow of hazardous substances may be of similar relevance as a high volume flow with a low specific impact.

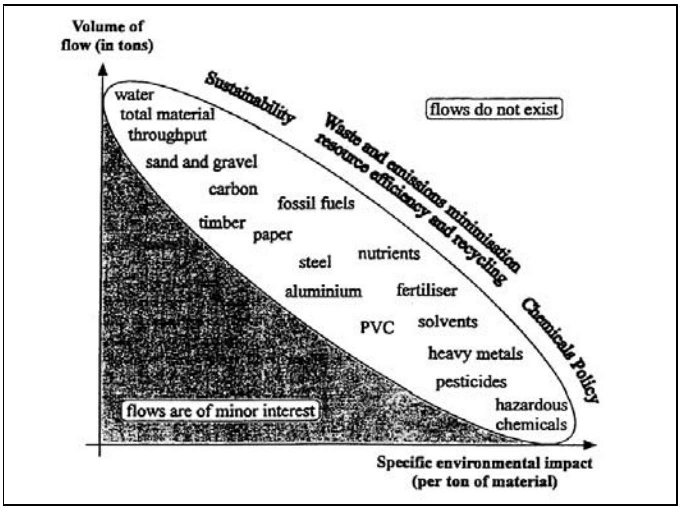

Figure 2-2: Stylised map of key material flows

Source: Steurer 1996

The lack of knowledge (no aggregated measure for environmental impacts) and the possibility of still unknown impacts may imply that for a considerable number of material flows the specific impact is not known. As long as this is the case, it may lead to the precautionary rationale that a volume reduction *ceteris paribus* also leads to a reduction of potential environmental impacts.

ad 2) Link between material inputs and outputs

Due to the law of conservation of matter, all material inputs from the environment will become material output flows to the environment sooner or later, i.e. the inputs determine the outputs at least in quantitative terms. The number of "entry points" of material inputs into the economy is much lower than the number of "exit points". Whereas a manageable number of raw materials (maybe around a hundred) are extracted by only a few sectors (agriculture, forestry, mining and quarrying, construction), the material outflows and their related "exit points" seem to be innumerable.

Material flows and their environmental impacts are induced at each stage of the production and consumption chain and three main interfaces where society directly interferes with nature in terms of material flows can be distinguished:

- the extraction/harvest of primary resources
- the final disposal of residuals (waste, emissions, dissipative use of products)
- the covering of nature (through material stocks of buildings and infrastructure)

The cause-effect relationships between material inputs and outputs and its life-cycle related impacts have only been analysed in a qualitative way so far (e.g. Schütz et al. 2000, see also chapter 6). Maybe it is best known for the case of fossil fuels which are predominantly transformed to CO_2 contributing to the climate change problem. A principal finding is that the use of main resources is always associated with a bundle of different impacts.

Conclusion:

- Material inflows, outflows and stock changes of the economy are the “carriers” of environmental pressures.

- Impact is a function of materials volume and specific impact per volume unit (see graph)

- One can distinguish substance specific and non-substance-specific environmental impact (potentials):
  (a) generic impact potential associated with the turnover of (primary) materials, and
  (b) substance related impact potential of specific pollutants.

- One may consider not only actual but also potential impacts (precautionary principle).

- The amount of material inflows determines the amount of material outflows and stock changes due to the conservation of matter.

- The use of main resources is always associated with a bundle of (potential) impacts.

The limited knowledge on the specific environmental impacts and the cause-effect linkages as well as the unfeasibility of generating this information in the mid to long-term may lead to the precautionary rationale that a strategy aiming at the reduction of the volumes of resource flows (the inputs of the societal metabolism) will also prevent environmental impacts. Accordingly, a final scientific assessment of the material volumes does not seem feasible yet and requires further analyses and research.

The material flow accounts for the EU and Accession Countries (as presented in chapters 4 and 5) provide first information on the volume and interlinkages of European resource and material flows. Hence, they can provide some general system characteristics of the industrial metabolism. In the future, a more in-depth analysis may be undertaken on specific impacts and cause-effect relationships which should nevertheless be comprehensive enough to consider all major inputs, stocks and outputs and their overall effect at the macro level.

It is expected that a political/normative assessment and priority setting – based on discursively obtained normative criteria – is required before full scientific proof will be available on the complex interlinkages between resource and material flows on the one hand and associated environmental impacts on the other.

3. Methodology: Material Flow Accounting (MFA)

Material Flow Accounting (MFA) comprises various descriptive and analytical tools to understand the functioning of the physical basis of societies, the interlinkages of processes and product chains, and the exchange of materials and energy with the environment in order to understand the interaction of human activities and the environment. Mass balancing is the common methodological element underpinning the different MFA tools. The different types of MFA depend on the primary interest of the analyst (Bringezu and Kleijn 1997, Bringezu and Moriguchi 2002), e.g. whether the focus is laid on specific substances or bulk material flows, or whether the geographical scale is local, regional or national.

The purpose of this study is to provide an overview of the material throughput of the economy of European countries (EU and AC)[5]. Towards this end, one particular MFA methodology is applied: “economy-wide material flow accounts (MFA)”. This approach has been laid down in a methodological guide (Eurostat 2001) jointly developed by statisticians and MFA experts.

Data from many statistical sources, ranging from agriculture and energy statistics over trade and production statistics to environmental statistics such as waste and air emissions, are integrated into an economy-wide MFA.

A number of aggregated indicators can be derived from MFA indicating the metabolic performance of an economy. A common feature of these MFA indicators is that they represent mass-turnover based non-specific[6] impact potentials and a generic environmental pressure of resource use. As outlined in section 2.3, they are complementary to substance specific indicators related to well-known environmental impacts. The study will not present information on substance specific impacts (e.g. global warming potential) as this would go beyond its scope and also due to the lack of knowledge and data concerning those impacts where no harmonised classification still exists (e.g. biodiversity, landscape changes, soil fertility, and reproduction capacity). The task to fill these gaps may be subject to further research. Insofar, the presented findings based on MFA and derived indicators cannot be solely used to finally assess and prioritise the EU’s resource use patterns.

3.1. Economy-wide MFA

Economy-wide MFA allow flow data to be organised in an integrated and systematic framework and provide an overview on the metabolism of a national economy. They are supposed to form a physical complement to the monetary System of National Accounts.

[5] European Parliament and the European Council (2002), article 8 (a): an estimate of materials and waste streams in the Community, including imports and exports for example by using the instrument of material flow analysis.

[6] With regard to substance composition, e.g. the impact of landscape change through soil excavation for infrastructure is independent of the chemical composition of the soil.

Economy-wide MFA are based on the mass balance concept and account systematically for all material input and output flows crossing the functional border between economy (technosphere, anthroposphere) and environment. They consider also all material flows crossing the national (geographical) border, i.e. imports and exports. The mass differences between material inputs and outputs relate to the physical stock changes within the national economy. At the overview level, economy-wide MFA do not account for the internal material flows within the economy (e.g. between production units)[7].

In economy-wide MFA a distinction is made

a. between used and unused extraction (the latter is not further processed and has no economic value although burdening the environment), and

b. between direct and indirect flows.

The latter comprise, for example, the upstream resource requirements (used or unused) associated with imports of an economy. The so-called "hidden" flows are either unused domestic extractions moved/removed in order to get access to the wanted raw materials (e.g. mining waste); these are termed "domestic hidden flows"; or, they are associated with imports and relate to the life-cycle-wide primary material requirements which had been necessary to produce the imported good; these are termed "foreign hidden flows"[8].

Figure 3-1 illustrates the different components of an economy-wide MFA.

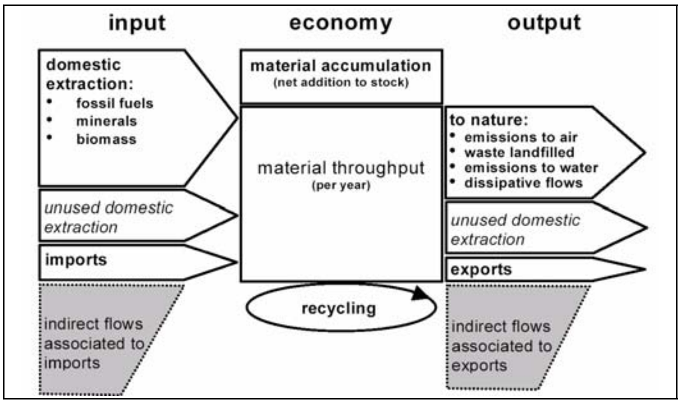

Figure 3-1: Main components of an economy-wide MFA (according to Eurostat 2001)

Source: Eurostat 2001

Inputs from the environment (material inputs, MI) are defined as the extraction or movement of natural materials on purpose and by humans or human controlled means of technology.

Outputs released to the environment (material outputs, MO) are materials leaving the technosphere whereby society is losing control over these materials.

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

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[7] Those are shown in more detail e.g. by Physical Input-Output Tables (PIOT).

[8] The correct term according to Eurostat (2001) is "indirect flows associated to imports"; in the literature they are sometimes termed "ecological rucksacks of imports".

1.	Used domestic extraction	i.e. raw material extractions from the domestic environment which are directly used in subsequent economic processing (e.g. fossil fuels, metals, industrial minerals, construction minerals, biomass etc.)
2.	Unused domestic extraction (domestic hidden flows)	i.e. those primary material inputs associated with the above-mentioned used domestic extractions which are not directly used in economic processing ("hidden") and hence are not valued economically (e.g. unused extraction from mining and quarrying (overburden), from biomass harvest (discarded by-catch, wood harvesting losses etc.), and soil (and rock) excavation and dredged materials (materials extracted during construction and dredging activities))
3.	Imports	i.e. the materials of goods imported to the national economy
4.	Indirect flows associated with imports (foreign hidden flows)	i.e. the "hidden" life-cycle-wide primary resource extractions that where required to produce the imported good (often referred to as "ecological rucksacks")

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

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

1.	Processed outputs to nature	i.e. the results of production or consumption processes, classified into o Emissions and waste flows o Dissipative use of products and dissipative losses
2.	Exports	i.e. the materials of exported goods
3.	Unprocessed outputs (disposal of unused domestic extraction)	equals the unused domestic extraction (domestic hidden flows)
4.	Indirect flows associated with exports	i.e. the "hidden" life-cycle-wide primary resource extractions that were required to produce the exported good (often referred to as "ecological rucksacks")

3.2. Main MFA indicators

A number of aggregated indicators can be derived from economy-wide MFA (see following overview).

The Eurostat MFA methodological guide stresses that the choice of the most relevant indicators is still open and will depend on the experiences to be made with policy analyses and policy applications of resource use indicators. "At present, good candidates for core indicators would be the input indicators DMI and TMR as well as the consumption indicators DMC and, maybe, TMC (the latter being difficult to estimate because of the need to estimate the indirect flows associated to exports). NAS and PTB may be interesting supplementary indicators" Eurostat 2001, p. 35). These indicators are briefly introduced in the following.

Table 3-1: Aggregated indicators derivable from economy-wide MFA (Eurostat 2001)

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

Note: HF: hidden flows; IF: indirect flows

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

+ (a) domestic extraction used (DE)
  - Fossil fuels (coal, oil…)
  - Minerals (metal ores, construction minerals, industrial minerals…)
  - Biomass (timber, cereals…)

+ (b) (physical) imports

= Direct Material Input (DMI)

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

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

First, hidden flows (HF) refer to materials which are extracted or otherwise moved by economic activities but which do not normally serve as input for domestic production or consumption (mining waste such as overburden, erosion in agriculture etc.). This “unused extraction” relates, for instance, to the hidden flows of primary production (either domestically or in foreign countries). These flows which are not further processed and have no economic utility (e.g. mining waste) nevertheless burden the environment, especially in the local and regional surroundings of the extraction site (landscape changes, hydrological impacts, sometimes eco-toxic effects).
Second, the hidden flows of imports comprise the “cradle-to-border” primary resource requirements which are linked to the provision of the imports (comprising upstream unused and used extraction).
Therefore, the TMR account comprises hidden flows in addition to DMI:

= Direct Material Input (DMI)
+ (c) unused domestic extraction
  - From mining/quarrying
  - From biomass harvest
  - Soil excavation (and dredging)
  - Erosion from agricultural land
+ (d) indirect flows associated to imports
= Total Material Requirement (TMR)

As for DMI, these main material categories are further detailed in the course of more detailed analysis needs.

DMC (*Direct Material Consumption*) is defined as the total amount of materials directly used in a national economy (i.e. excluding indirect flows) and consumed by domestic actors (i.e. exports are substracted). DMC is defined in the same way as other key physical indicators such as gross inland energy consumption[9]. DMC equals domestic used extraction plus imports minus exports (or more simply DMI minus exports):

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

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

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

NAS (*Net Additions to Stock*) measures the “physical growth of the economy”, i.e. the quantity (weight) of materials net added to the stock of buildings and other infrastructures, materials incorporated into new durable goods such as cars, industrial

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[9] Energy balances by the International Energy Agency (IEA) use the term “Primary Energy Supply” whereas the Eurostat energy balances use the term “Gross Inland Energy Consumption”.

machinery, and household appliances. In principal, NAS equals the DMI minus exports minus DPO[10]:

= Direct Material Input (DMI)
− (physical) exports
− Direct Processed Outputs (DPO)
= Net Additions to Stock (NAS)

PTB (*Physical Trade Balance*) is defined as the physical trade surplus or deficit of an economy. PTB equals imports minus exports.

+ (physical) imports
− (physical) exports
= Physical Trade Balance (PTB)

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

Economy-wide MFA and derived indicators have certain strengths and certain limitations – a systematic overview is given in the following table.

Table 3-2: Strengths and limitations of economy-wide MFA and derived indicators

STRENGTHS	LIMITATIONS
MFA provides an overview of the metabolism of the economy, and retrospective analysis of the dynamics of volume and structure	Status quo and current trends do not indicate a possibly sustainable future situation; for that purpose integrated scenarios and prospective modelling is required
Economy-wide MFA provides the link between economic activities of a national economy and environmental impacts through pressure indicators, either on the output side (e.g. GHG emissions) or on the input side (e.g. TMR)	The indicators do not tell anything about impacts in terms of changes of the state of environment (neither output nor input related pressures do so)
Input based indicators quantify also the amount of subsequent output	Output indicators are not as easy and accurate to provide as input indicators
Indicators such as TMR account for the overall requirements of primary materials (analogous to primary energy consumption, but considering energetic and non-energetic materials as well as “embodied” requirements)	In order to do so one has to define (1) when a resource use is “primary” (where does the “cradle” stand?); (2) which resources are to be accounted for; because several different primary materials (metals, industrial minerals etc.) are used, the total amount of primary resource requirements has to add up different materials; as a consequence, the results are dependent on accounting conventions (laid down e.g. in the Eurostat guide) which may define the system boundary and the categories to be considered in different ways, depending on the objectives of interest
Bulk material flow indicators such as TMR may be interpreted as indicators of generic environmental pressure which give rise to a bundle of consequences or impacts irrespective of the chemical composition; e.g. indicating the total amount of wastes and emissions to be expected as a consequence of resource input, and/or indicating a risk of unclassified or non-	Bulk material flow indicators may not be used to indicate substance specific pressures (e.g. GWP); therefore, the risks associated with resource use can only be reduced by considering the overall amount of primary resource input *as well as* specific hazardous emissions

[10] The following account only holds if certain balancing items are considered: on the input side oxygen for combustion and on the output side water vapour from combustion have to be considered.

quantifiable impacts at the macro level (through landscape changes, loss of fertile soil etc.)	
Bulk material flow indicators may be designed to indicate the flows induced by the production (DMI, TMR) or consumption (DMC, TMC) side of the economy, as well as the resulting efficiencies (relations to GDP)	There is no single indicator serving all of these purposes
Used and unused inputs can be accounted for; with regard to the impacts of resource extraction or harvest there is no general difference with regard to the subsequent routes of processing, or whether some of the materials will be assigned an economic value later	Unused extraction may have different impacts than further processed materials with regard to the subsequent outputs; therefore, the information on overall inputs should be complemented by the information on critical outputs
Domestic and foreign material flows associated with domestic activities can be accounted for in order to detect shifts of environmental burden and of dependence on foreign resources	Data availability and accuracy of hidden flows of imports and exports is lower than for domestic material flows DMI and DMC do not account for foreign resource requirements and cannot be used to detect those shifts
MFA allows to distinguish between renewable and non-renewable inputs	Renewables may stem from unsustainable cultivation or harvest; therefore the information on renewables should be further qualified in future
MFA allows to quantify the physical growth of the technosphere as an indicator of future waste volumes and of the distance from flow equilibrium (which is one precondition of a sustainable situation)	Assessing the implications of the expansion of the technosphere requires consideration of land use; an integrated resource management will have to consider material, energy and land resources

3.3. Data sources

The MFA data sets for the European Union used in this study stem from Eurostat projects (Eurostat 2001, 2002). The MFA data set for the Accession Countries has been compiled by the Wuppertal Institute in a separate project for the ETC/WMF (Schütz et al. 2002). The three MFA data sets have been numbered A, B, and C.

Data set A: European Union (EU-15) 1980-1997
The Wuppertal Institute produced a first estimate of aggregate material use in the EU covering the period 1980-1997 for Eurostat and DG Environment. The results as well as the data sources and methods are documented in Eurostat 2001: Material use indicators for the EU 1980-1997 (Catalogue No. KS-AO-01-002-EN-I). Key results from this first estimate were included in Eurostat 2001: Measuring progress towards a more sustainable Europe (2001, Catalogue No. KS-37-01-203-EN-N) and in the EEA's Environmental Signals 2002.

Data set B: European Union (EU-15) 1980-2000
In another recent Eurostat project, the Wuppertal Institute's 1980-1997 data were revised and updated to 1980-2000 by the Department of Social Ecology of the Institute for Interdisciplinary Studies of Austrian Universities (IFF). The project only updated and revised the DMI, i.e. did not include "hidden flows" and hence no TMR.
The update included a revision of the historical time series. Major work was done checking and comparing the accounts already available nationally with the help of the Member States, and checking the international data sources for completeness so as to

increase the comparability of the results across countries. Some estimation methods were also revised. The revision affected the estimated *level* of key indicators such as the direct material input – DMI, reducing the totals of this indicator by about 15%. Hence, comparability between data set B with the other two is limited. The impact on the trends over time was less pronounced.

Data set C: Accession Countries (AC-13) 1992-1999
Data have been compiled by the Wuppertal Institute in a separate project for the ETC/WMF (Schütz 2002, a brief methodological description can be found in the appendix to this study). Due to statistical data availability, time series comprise only the domestic extraction and imports (which can be aggregated to the DMI indicator) for the period of 1992 to 1999.

Table 3-3: Overview of MFA data sources

Set	Authors	Reference	Geographical coverage	MFA items	Level of dis-aggregation	Time coverage
A	Eurostat & Wuppertal Institute	Eurostat 2001	EU-15 as an aggregate, no systematic country breakdown, however data for selected Member States	+ domestic extraction used (DE) + (physical) imports = Direct Material Input (DMI) + unused domestic extraction + indirect flows associated to imports = Total Material Requirement (TMR) − (physical) exports − Direct Processed Outputs (DPO) = Net Additions to Stock (NAS) Physical Trade Balance (PTB)	1st level: - fossil fuels - metals - industrial minerals - construction minerals - biomass 2nd level: commodity groups	1980 - 1997
B	Eurostat & IFF	Eurostat 2002	EU-15 as an aggregate, breakdown by 14 Member States	+ domestic extraction used (DE) + (physical) imports = Direct Material Input (DMI) − (physical) exports = Direct Material Consumption (DMC) Physical Trade Balance (PTB)	1st level: - fossil fuels - industrial minerals and ores - construction minerals - biomass	1980 - 2000
C	Wuppertal Institute	Schütz 2002	13 Accession Countries	+ domestic extraction used (DE) + (physical) imports = Direct Material Input (DMI)	1st level: - fossil fuels - metals - industrial minerals - construction minerals - biomass	1992 - 1999

For several reasons, comparability between the three data sets is to some extent restricted. The main restrictions are:

- There are some differences with regards to the methodology applied to compute domestic extraction of biomass (in particular grazing) between data set A and C on the one hand and data set B on the other hand. These methodological differences have led to a structural lower level of biomass from grazing in data set B (see Eurostat 2002).

- In general, data quality for "hidden" (indirect) flows associated with imports is lower than for the other components since they have to be estimated using coefficients derived from LCA-type studies and other information. In general, those "hidden" flows coefficients are only available for imported raw materials and semi-manufactured goods, i.e. for final goods no estimations of “hidden” flows are considered. This implies that the “hidden” flows to imported goods are structurally too low.

Whereas for the MFA aggregates of the EU foreign trade between the 15 Member States (intra-EU-trade) has been eliminated, the aggregated data for Accession Countries do include intra-trade between the 13 economies. This leads to a structurally higher figure for MFA aggregates such as DMI.

A first attempt to attribute material input flows to economic sectors has been performed in section 4.9. For a more sophisticated sectoral attribution, physical input-output modelling is needed. However, physical input-output tables have been compiled only for a small number of countries and are not available for the EU as a total.

In addition to the MFA data sets, further statistics have been used for this study (chapter 6) , in particular several international minerals and energy statistics (British Geological Survey 2002, European Commission 1998, USGS 2001, IEA 2001).

4. Material Flow Accounts for the European Union

This chapter provides an overview of the materials resource use trends of the EU based on the MFA data sets A and B. Main findings are:

- EU's material use and resource requirements have been rather constant over the last decades, thereby decoupling relatively from economic growth; resource productivity has increased.

- The composition of the EU's DMI and TMR is characterised by a dominant share of non-renewables (74% and 88%).

- With 50 tonnes per capita the level of EU's TMR is comparable to that of Japan, lower than that in USA, and within a range of around 32 t/cap in Italy and almost 100 t/cap in Finland.

- Aggregate MFA indicators (DMI, DMC, TMR) change very little over time – as is the case for energy aggregates. This implies that a change in the structural characteristics of EU's resource-use patterns would require long-term policies. The moderate changes seem to be closely linked to economic events (e.g. aftermath of the second oil crisis in the early 1980ies, economic recession in 1993).

- A considerably high amount of around 60% of the annual direct material inputs increases the material stock of the economy (about 10 t/cap). At present, this physical growth is closely related to the growth of built-up areas and energy requirements for maintenance of buildings and infrastructures. In future, generation of construction waste will increase.

- The other approx. 40% of direct material inputs is balanced by the same amount of processed outputs to the environment in the form of air emissions, waste, waste water and dissipative losses.

- EU's resource requirements are increasingly met through imports, particularly metals and industrial minerals. The indirect "hidden" flows associated with imports are showing an increasing trend.

- Use of fossil fuels (in particular associated "hidden flows") has decreased significantly during the 1990ies mainly due to a changed mix of energy carriers from coal towards oil and gas. Restructuring of Germany's energy sector significantly contributed to this development.

4.1. Overview – economy-wide material balance and aggregate MFA indicators for EU

4.1.1. Economy-wide material balance

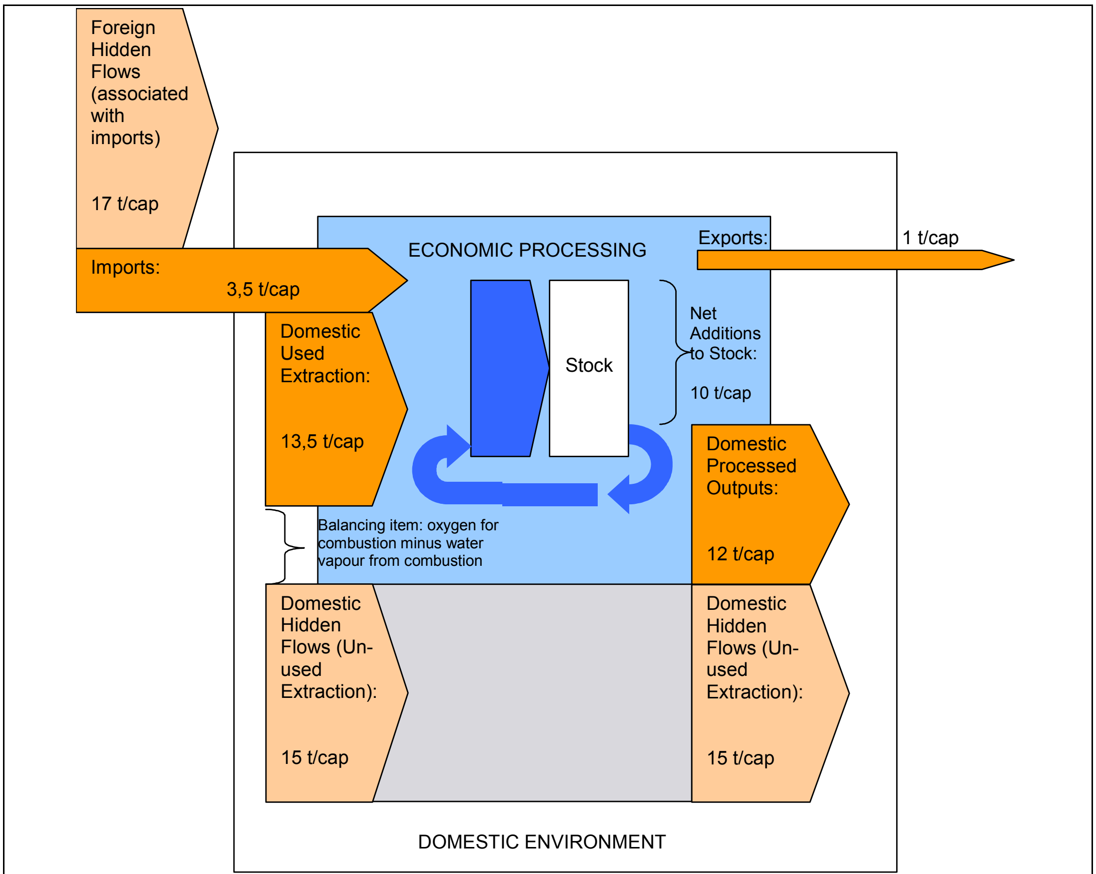
Due to the law of conservation of matter, all resource inputs to the economy either become an output or are added to the physical stock. The metabolism of an economy can hence be summarised in terms of a material balance.

Figure 4-1 provides an estimate of the metabolism of the EU economy on an annual per capita basis for the second half of the 1990ies.

The EU economy directly takes in about 17 tonnes raw materials per capita for further processing in the production system (DMI). The directly used material input comprises about 13.5 t/cap of domestically extracted material and about 3.5 t/cap of imports.

Another significant part of the domestic extraction has no further use and is shifted aside in terms of mining waste such as overburden, waste rock and tailings. For the EU, this amounts to about 15 t/cap. These so-called hidden flows impact on the domestic environment, pollute groundwater and contribute to landscape change and constitute a major part of the domestic material outputs in terms of mining wastes.

There are also “hidden flows” associated with the imports, i.e. life-cycle-wide primary resource extractions from the foreign environment which were necessary to produce the imported goods. These are estimated to amount to about 17 t/cap for the EU imports.



Source: Wuppertal Institute

Figure 4-1: Estimated economy-wide material flows in the EU, on a per capita and year basis and for the second half of the 1990ies

A significant amount of the direct material inputs is stored in the physical stock of the EU; this concerns in particular construction minerals. The net additions to the stock of buildings, infrastructure and consumer durables are estimated to be around 10 t/cap for the EU.

During use in the economic system, fossil fuels in particular are transformed and immediately released into the environment in terms of air emissions. After use, products become waste and may be recycled or finally disposed of in landfills or incineration plants. These outputs from processing to land, air and water amount to about 12 t/cap in the EU. Of those, air emissions constitute the bulk with some 10-11 t/cap, of which more than 95% is CO_2. About 1 t/cap of the processed output is actually waste landfilled and some minor 300 kg/cap are dissipative uses of products (e.g. fertilisers) and dissipative losses from product use (e.g. from tyres).

4.1.2. DMI – Direct Material Input

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 domestic production and consumption activities, including materials used for producing export goods. DMI equals domestic (used) extraction plus imports. DMI is not additive across countries. For example, for DMI of the EU, intra-EU foreign trade flows are netted out from the sum of DMIs of Member States (Eurostat 2001, p. 35).
In 2000, the DMI of EU-15 amounted to about 16.8 tonnes per capita and was composed as follows (Figure 4-2): About 40% of DMI is determined by construction minerals. Biomass and fossil fuel amount to one fourth each. With some 9%, industrial minerals and metal ores play a minor role within DMI.
The major part of EU's DMI is formed by non-renewable resources, i.e. about 74%.

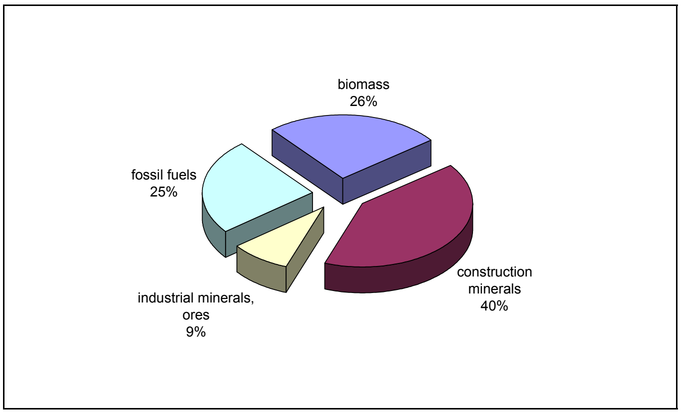


Figure 4-2: Composition of DMI, EU-15 2000

Source: Eurostat & IFF (2002), data set B

From 1980 to 2000 Direct Material Input (DMI) into the economy of the European Union (EU-15) ranged between 5.7 to 6.4 billion tonnes or 15.9 to 17.5 tonnes per capita respectively (Figure 4-3). After a slight increase in the second half of the 1980ies it remained more or less on this slightly higher level in the 1990ies.

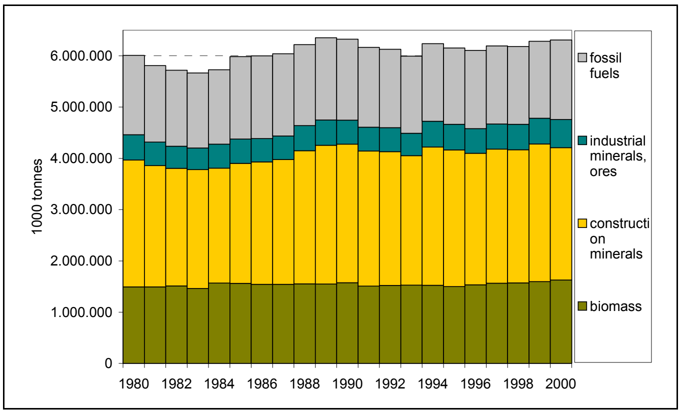


Figure 4-3: DMI by main material categories, EU 1980-2000, in absolute billion tonnes

Source: Eurostat & IFF (2002), data set B

The single components of DMI also developed differently over the observation period (Figure 4-4). The metal component (including industrial minerals here) shows a significant increase up from 1993. Construction minerals kept below the 1980 value until 1987, since then construction minerals have constantly been slightly above the 1980 value. The fossil fuel component of DMI decreased during the 1990ies slightly. Only biomass is showing a steady increase, though with moderate growth rates.

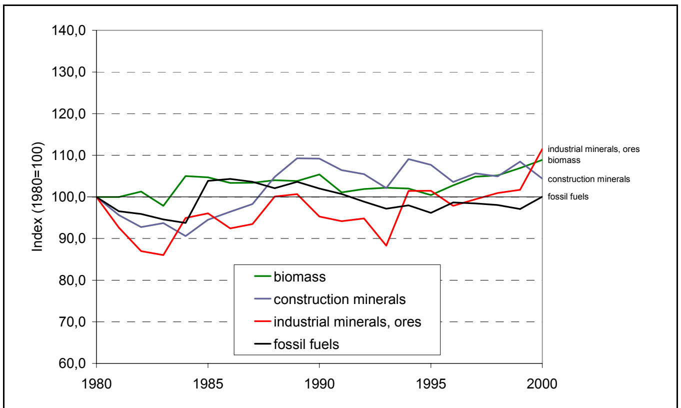


Figure 4-4: Development of single components of DMI, EU-15 1980-1997 (Index: 1980=100)

Source: Eurostat & IFF (2002), data set B

The foreign part of DMI, i.e. the net weight of imported goods to the EU economy, was around 12% of DMI during the 1980ies and increased to around 16% at the end of the 1990ies, i.e. from 3.1 to 3.8 tonnes per capita (Figure 4-5).

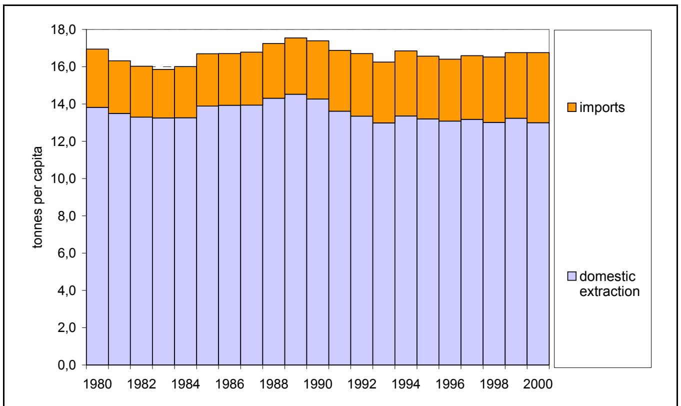


Figure 4-5: DMI distinguished by foreign versus domestic, EU 1980-2000, in per capita tonnes

Source: Eurostat & IFF (2002), data set B

4.1.3. DMC – Direct Material Consumption

Domestic material consumption (DMC) measures the total amount of material directly used in the consumption activities of an economy (i.e. excluding indirect or "hidden" flows). DMC is defined in the same way as gross inland energy consumption[11].
DMC equals domestic used extraction plus imports minus exports (or more simply DMI minus exports):

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

On the aggregate EU level, DMC has developed more or less in parallel to DMI. After a decline in the early 1980ies, DMC grew from 15.0 tonnes per capita in 1983 up to 16.7 tonnes per capita in 1989. After a slight decrease in the early 1990ies, it stayed fairly constant at around 15.5 tonnes per capita in the second half of the 1990ies.

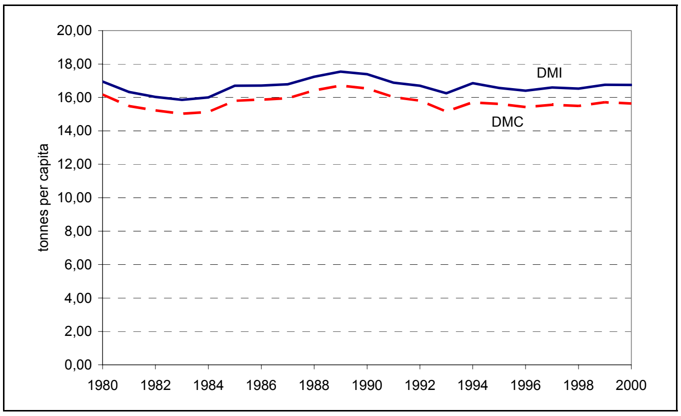


Figure 4-6: DMC (direct material consumption) compared to DMI, EU 1980-2000 – per capita

Source: Eurostat & IFF (2002), data set B

A different picture occurs when looking at the different Member States. The following figure compares the DMI and DMC for the single Member States and the total EU-15 for the latest available year 2000 and ranked by their DMC per capita.
The DMC per capita varies significantly across Member States from about 12 t/cap (UK) to about 35 t/cap (Finland).
The difference between DMI and DMC also varies significantly across the Member States. It reflects the physical external trade patterns since the difference is made up by exports. Particularly visible is the "Rotterdam effect", i.e. the difference between DMI and DMC which is extremely high for the Netherlands and Belgium/Luxemburg due to their important harbours constituting gateways of extra-EU trade for many Member States of the EU.

[11] = Primary Energy Supply (IEA/OECD).

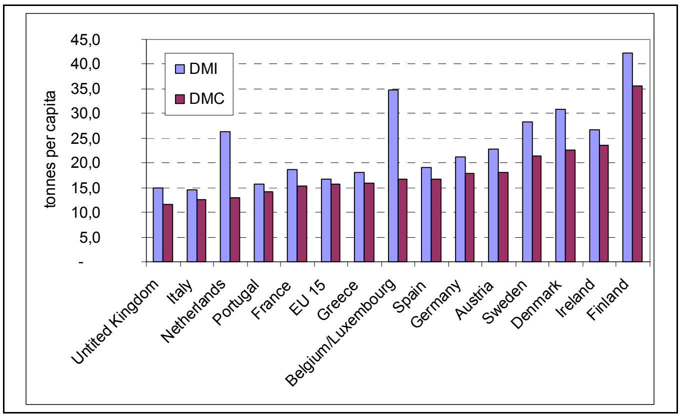


Figure 4-7: Comparison of Direct Material Consumption (DMC) and Direct Material Input (DMI) in the EU and in Member States for the year 2000, tonnes per capita

Source: Eurostat & IFF (2002), data set B

The following table shows the above-introduced elements (domestic extraction, imports, DMI, exports, DMC) for the 15 Member States and total EU and for the latest available year 2000. It shows again the "Rotterdam effect" for the Netherlands and Belgium/Luxemburg where the DMC account for less than 50% of DMI. It also shows that none of the EU Member States is apparently self sufficient[12] in its resource basis, i.e. physical exports are below imports, or in other words, DMC is above domestic extraction in all Member States.

Table 4-1: Direct material input and consumption account, EU-15 and Member States 2000

unit: DMI = 100	**Domestic extraction used**	**+ Imports**	**= DMI**	**- Exports**	**= DMC**
	1	*2*	*3 = 1 + 2*	*4*	*5 = 3 − 4*
EU 15	78	22	100	7	93
Belgium/Luxembourg	32	68	100	52	48
Netherlands	32	68	100	51	49
Denmark	73	27	100	26	74
Sweden	76	24	100	25	75
United Kingdom	77	23	100	22	78
Austria	65	35	100	21	79
France	69	31	100	18	82
Finland	75	25	100	16	84
Germany	71	29	100	16	84
Italy	61	39	100	14	86
Spain	71	29	100	12	88
Greece	72	28	100	12	88
Ireland	69	31	100	11	89
Portugal	68	32	100	10	90

Source: Eurostat & IFF (2002), data set B

4.1.4. TMR – Total Material Requirement

DMI and DMC do not consider "hidden flows", i.e. the unused domestic extraction such as mining wastes including overburden, and the "indirect" life-cycle-wide primary resource requirements associated with imports. Total Material Requirement (TMR) is a summary measure that accounts for the total use of natural resources (without water and

[12] Self-sufficiency is usually only related to a specific resource and its substitutes; if DMC were equal to domestic extraction this would not exclude a dependence on certain imports; however, this would be balanced by exports of other products which stem from the domestic resource base.

air) that national economic activity requires (Adriaanse et al. 1997, p. 1). The TMR takes into account both, hidden flows and foreign components of natural resource use, as well as direct inputs of natural resources into the economy.
In 1997, the TMR of EU-15 amounted to about 51.4 tonnes per capita and was composed as follows (Figure 4-8): About 28% of TMR was determined by fossil fuels. Metals constituted the second biggest component with some 23%, followed by construction minerals accounting for 18% of the TMR. Related to the latter are excavation and dredging, accounting for a further 6% of TMR. Biomass and erosion were responsible for 12% and 9% respectively. With some 3%, industrial minerals played a minor role as did other – not attributable – imports with 1%.
The major part of EU's TMR is formed by non-renewable resources, i.e. about 88%.

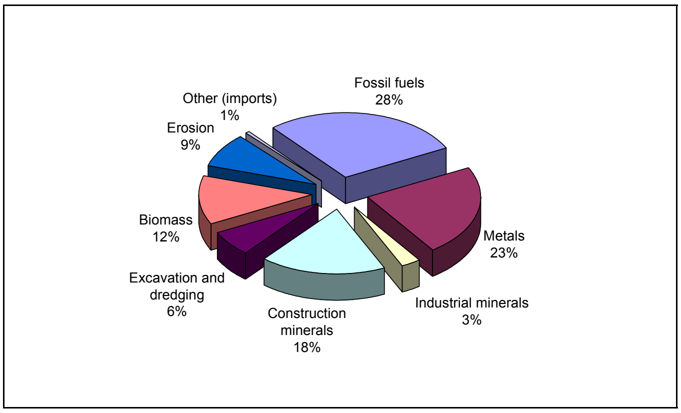


Figure 4-8: Composition of TMR, EU-15 1997

Source: Eurostat & Wuppertal Institute (2001), data set A

With around 50 tonnes per capita, the overall resource requirements of the European Union is on a medium level compared to other economies such as the United States with about 80 t/cap (Adriaanse et al. 1997), Japan with about 45 t/cap (Adriaanse et al. 1997), and China with about 37 t/cap (Chen and Qiao 2000). No single determinant could be identified so far explaining the different resource-use levels worldwide. A number of factors seem to be of relevance such as:

- the level of economic development (GDP per capita) and the volume of production and consumption;
- the technology used and the way of production and consumption;
- the domestic availability of natural resources (land, raw materials, climate);
- the size of the economy (e.g. the smaller the economy, the higher are external trade relations); and
- population density.

From 1980 to 1997, Total Material Requirement (TMR) of the European Union (EU-15) fluctuated between 17.5 and 20 billion tonnes. On a per capita basis this was around a level of 50 tonnes per capita. The moderate changes seem to be closely linked to economic events (Figure 4-9), such as the economic recession in 1993, and the economic structural changes induced by Germany's reunification in the early 1990ies .

From 1980 to 1983 TMR of the EU-15 fell slightly from 18.4 to 17.7 billion tonnes, i.e. from about 52 to 49 tonnes per capita (Figure 4-9). TMR increased to slightly higher average levels after 1984 and reached a maximum of 20.1 billion tonnes or 56 tonnes per capita in 1989. From 1990 to 1993 TMR declined to about 18.3 billion tonnes or 49 tonnes per capita. The decrease was mainly determined by reduced fossil fuel use, particularly unused domestic extraction ("hidden flows") from lignite mining in former Eastern Germany. Lignite had been the main energy source of the former GDR, and with the reunification of Germany the indirect subsidisation of this resource use was significantly reduced. After 1993, TMR remained with slight variations at a level around 18.6 to 19.2 billion tonnes or 50 to 52 tonnes per capita until 1997.

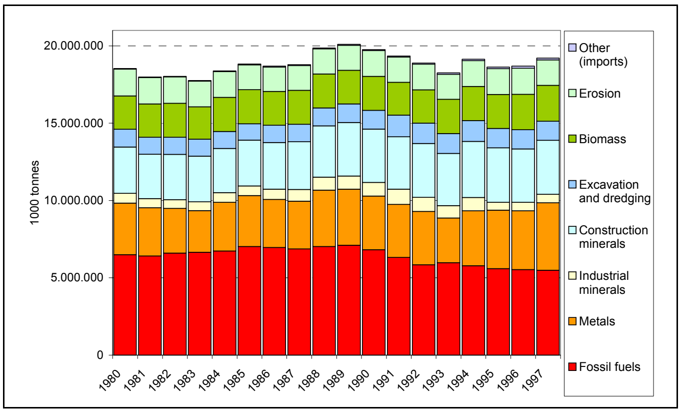


Figure 4-9: TMR over time by main material categories in absolute thousands tonnes

Source: Eurostat & Wuppertal Institute (2001), data set A

The single components of TMR developed differently over the observation period which can be shown best by indexing the particular TMR components (Figure 4-10).

Over the study period, the strongest increase of some 30% can be observed for the metal component of TMR. After it had been fluctuating during the 1980ies and early 1990ies, it steeply increased up from 1993 due to a shift from domestic extraction to import of metals. The construction minerals component of TMR increased steadily by about 17%. On the other hand, the fossil fuel component of TMR steadily decreased from 1989 after it had been rising during the 1980ies. Again, this is mainly attributable to the changed energy-mix.

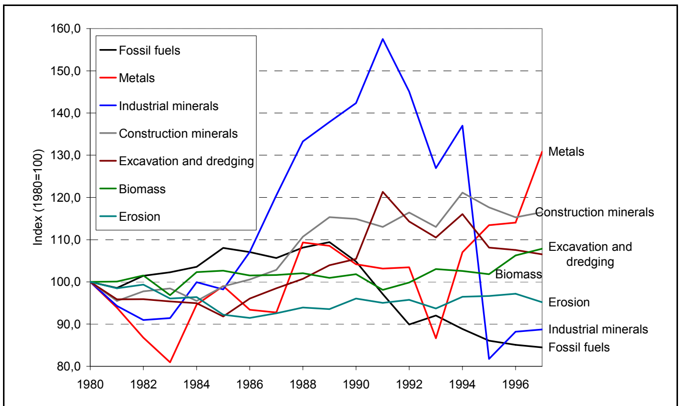


Figure 4-10: Development of single components of TMR, EU-15 1980-1997 (Index: 1980=100)

Source: Eurostat & Wuppertal Institute (2001), data set A

The 'hidden' part of TMR, i.e. materials not directly entering the economy like mining overburden and 'ecological rucksacks' of imported goods, accounts for almost two thirds. The hidden share slightly decreased from 64% during the 1980ies to 62% in 1997. Vice versa, only about one third of TMR is actually processed and consumed in the economy of the European Union.

The domestic part is about two thirds of total TMR and the foreign part one third respectively. However, the resource supply of the EU is undergoing a certain shift from domestic towards foreign resources (Figure 4-11).

The domestic part of TMR has been tending to decrease since 1989. Whereas the directly used part of domestic extraction remained constant at around 15-16 t/cap, the domestic “hidden flows” did decrease from the early 1990ies, mainly due to reduced unused extractions associated with lignite mining in former Eastern Germany.

The foreign part of TMR has been increasing significantly since the late 1980ies from around 30% to almost 39% in 1997. The increase of the directly used imports was less pronounced than the growth of the “hidden flows” of the imports.

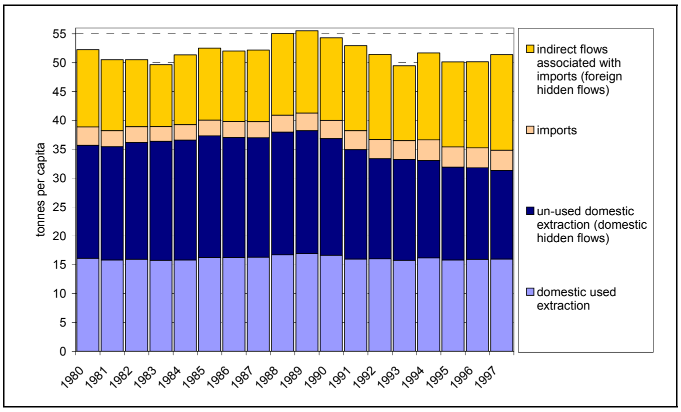


Figure 4-11: TMR over time distinguished by foreign versus domestic and hidden versus used, i.e. four groups in per capita tonnes

Source: Eurostat & Wuppertal Institute (2001), data set A

4.1.5. PTB – Physical Trade Balance

As already indicated in the previous section, the EU economy is a net importer in physical terms.

Physical imports into the EU significantly decreased in the early 1980ies from more than 1.1 billion tonnes in 1980 to almost 0.9 billion tonnes in 1983 due to a significant reduction of fossil fuel imports which may be regarded a consequence of the second oil crisis in 1979/80. From 1983 physical imports steadily rose again until 2000 to more than 1.4 billion tonnes (3.76 t/cap) with a short interruption in 1993. Physical imports account for about 5-7% of TMR and 16-22% of DMI with an increasing trend.

Physical exports have been on a significantly lower level than physical imports to the EU. During the 1980ies physical exports increased slightly up to around 320 million tonnes. In 1993-1994 the physical exports exceeded 400 million tonnes but dropped again down to 360 million tonnes in 1995/96. Since then, exports have been increasing again to 420 million tonnes in 2000 (1.1 t/cap). Physical exports account for 1-2% of TMR and 5-7% of DMI with a slightly increasing trend.

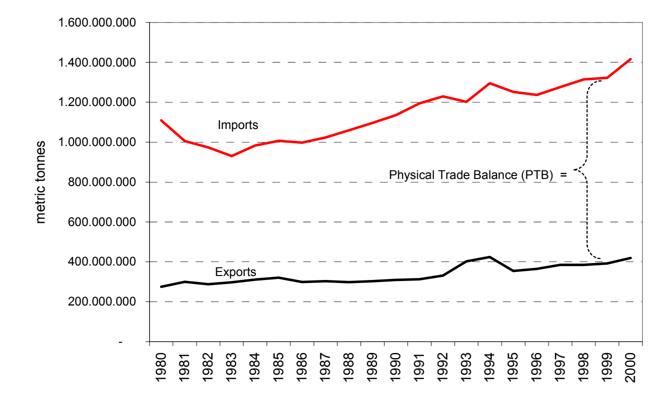


Figure 4-12: Physical imports and exports, EU 1980-2000 – absolute

Source: Eurostat & IFF (2002), data set B

Over the past decades EU external trade in physical terms did increase slightly – after a short but considerable drop in the early 1980ies. The Physical Trade Balance (PTB), which is imports minus exports, dropped from 2.4 tonnes per capita in 1980 to almost 1.8 tonnes per capita in 1983 and grew again back to a level of 2.6 tonnes by the end of the 1990ies.

Increasing trade volumes reflect the growing relevance of international trade flows due to globalisation. The growing trade balance indicates a shift in the structure of the trade in so far as the imports of the EU are increasingly related to mass supply (of raw and base materials) whereas the exports are dominated by lower volumes (of manufactured goods).

Fossil fuels constitute the main component of PTB with some 1.8 tonnes per capita. The net surplus of fossil fuels has been rising over the last two decades. The net imports of industrial minerals and metal ores have also been rising over the observation period whereas the net import of biomass has been falling slightly.

The continued surplus of the PTB indicates that there is a net inflow of material into the territory of the EU where it either contributes to the stocks of buildings and infrastructures (and thus to the problems associated with NAS, see below), or – and with respect to the nature of the flows this is much more the case – leaves the economy as an outflow to the EU environment (as waste or emission to air and water). In any case, the surplus of the PTB indicates a certain distance from a more balanced situation.

A more detailed assessment of PTB may be related to a specification of certain substances (e.g. phosphorous or nitrogen) – which is beyond the scope of this study.

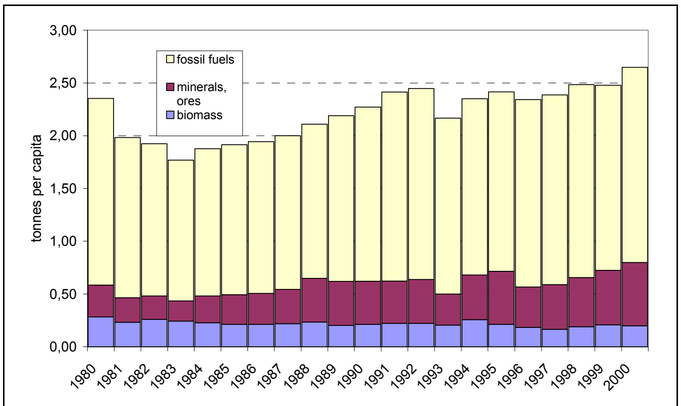


Figure 4-13: PTB, Physical Trade Balance by main material categories, EU 1980-2000, per capita

Source: Eurostat & IFF (2002), data set B

The physical trade figures vary across the Member States. In contrast to the EU, the figures for the Member States consider intra-EU-trade.

The following graph shows on a per capita basis the physical exports and imports, ranked by the latter, for the EU Member States and the year 2000. Again, the "Rotterdam effect" for the Netherlands and Belgium becomes visible. Physical imports and exports are nearly balanced in Denmark, Sweden and the UK since these countries are more involved in the export of raw materials (such as fossil fuels in UK and Denmark, and minerals in Sweden). For the southern Member States and Ireland, the difference between imports and exports is relatively the highest.

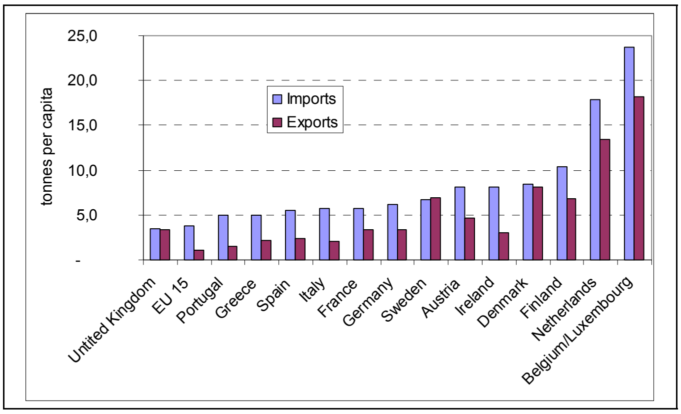


Figure 4-14: Physical imports and exports in EU Member States for the year 2000, tonnes per capita

Source: Eurostat & IFF (2002), data set B

4.2. Fossil fuels

As outlined in the overview sections above, fossil fuels account for about one fourth of the resource base of the EU economy (28% of TMR, 25% of DMI). About half of the fossil fuel requirements are domestically extracted and the other half is imported, whereby the latter is increasing on the account of the former.

In the shadow of the second oil crises, EU domestic used extraction of fossil fuels increased in the first half of the 1980ies from about 850 million tonnes to more than 1000 million tonnes. From the mid-1980ies, it continuously decreased to a level of slightly above 710 million tonnes or 1.9 t/cap respectively at the end of the 1990ies. On the other hand, imports of fossil fuels steadily increased from the mid-1980ies from 560 million tonnes in 1983 up to more than 830 million tonnes or 2.2 t/cap respectively in the year 2000. By this development, the imports increased their share from less than 40% to almost 55% of total fossil fuels.

The DMI of fossil fuels (i.e. adding domestic extraction (used) and imports of fossil fuels) remained rather constant on a level of 1.5 billion tonnes (around 4 t/cap) throughout the 1990ies after it had exceeded 1.6 billion tonnes at the end of the 1980ies.

The EU is exporting only minor amounts of fossil fuels – compared to the DMC about 5-10% – however with a steadily increasing trend throughout the observation period. It doubled from 67 million tonnes (0.19 t/cap) in 1980 to 137 million tonnes (0.36 t/cap) in the year 2000.

Balancing the above elements (Table 4-2) leads to the Domestic Material Consumption (DMC) of fossil fuels, i.e. the apparent consumption of fossil fuels within the EU economy. DMC of fossil fuels slightly decreased from more than 1.5 billion during the first half of the 1980ies – also a reaction to the second oil crisis. It recovered up to this level again in the second half of the 1980ies. During the 1990ies DMC of fossil fuels slightly decreased to a level of around 1.4 billion tonnes and 3.7 tonnes per capita respectively.

Table 4-2: Fossil Fuels – Direct material input and consumption accounts, EU-15, 1980-2000

		1980	1985	1990	1995	2000
		1000 tonnes				
	Domestic extraction used (DE)	854 338	1 018 469	898 515	745 998	716 813
+	Imports	694 095	589 827	681 210	742 998	832 567
=	DMI	1 548 433	1 608 296	1 579 725	1 488 996	1 549 381
−	Exports	66 873	80 553	80 716	111 475	136 553
=	DMC	1 481 559	1 527 744	1 499 009	1 377 521	1 412 828
		tonnes per capita				
	Domestic extraction used (DE)	2.41	2.84	2.47	2.01	1.90
+	Imports	1.96	1.65	1.87	2.00	2.21
=	DMI	4.37	4.49	4.34	4.01	4.12
−	Exports	0.19	0.22	0.22	0.30	0.36
=	DMC	4.18	4.26	4.12	3.71	3.75
		% of DMI				
	Domestic extraction used (DE)	58	67	60	54	51
+	Imports	47	39	45	54	59
=	DMI	105	105	105	108	110
−	Exports	5	5	5	8	10
=	DMC	100	100	100	100	100

Source: Eurostat & IFF (2002), data set B

The domestic extraction of fossil fuels is composed differently than the imports of fossil fuels (Figure 4-15 and Figure 4-16).

Domestic extraction of fossil fuel is dominated by lignite which accounts for one third (34%). It is followed by gas (27%) and oil (21%). Hard coal accounts for some 16% and other fuels for 2%.

Imports of fossil fuels are clearly dominated by oil which accounts for two thirds (66%). Hard coal forms about one fifth (19%) of imported fossil fuels and gas accounts for 14%.

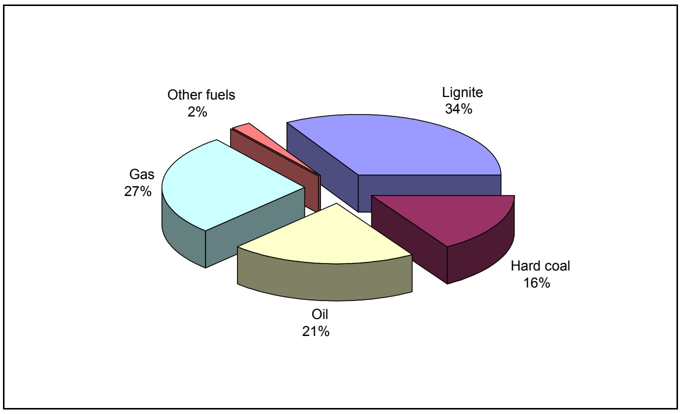


Figure 4-15: Composition of domestically extracted fossil fuels – EU-15, 1997

Source: Eurostat & Wuppertal Institute (2001), data set A

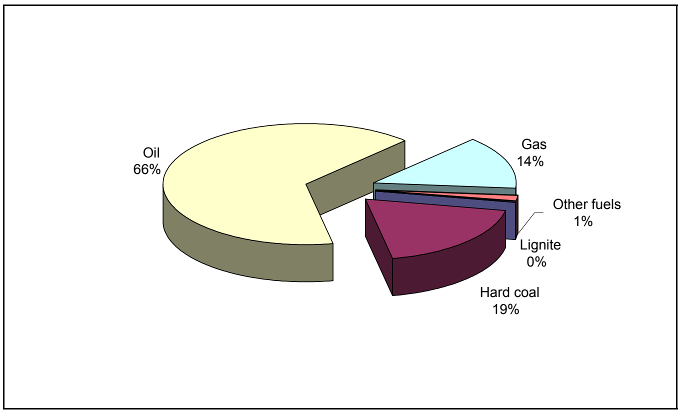


Figure 4-16: Composition of imported fossil fuels – EU-15, 1997

Source: Eurostat & Wuppertal Institute (2001), data set A

If one considers the "hidden flows" associated with the domestic extraction and import of fossil fuels, i.e. the TMR of fossil fuels, the following picture is revealed (Figure 4-17): Throughout the 1980ies, the TMR of fossil fuels amounted to more than 19 tonnes per capita and has been decreasing to about 14 t/cap since then. The amount of domestic and foreign "hidden flows" is higher than the direct used fossil fuels.

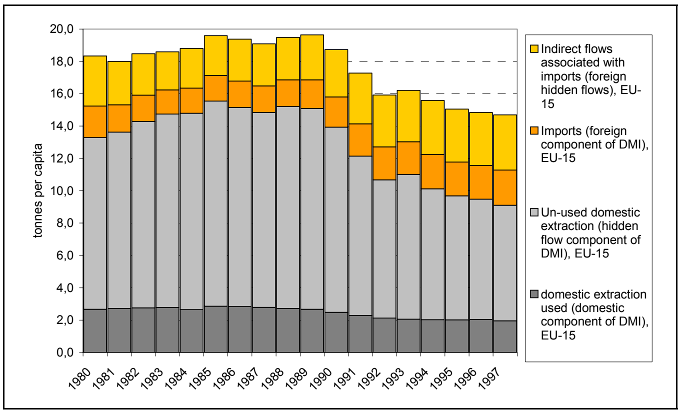


Figure 4-17: TMR of fossil fuels – EU-15, 1980-1997

Source: Eurostat & Wuppertal Institute (2001), data set A

The "hidden flows" associated with imports of fossil fuels have been ranging from 840 to 1270 million tonnes, which is roughly one third above the weight of the imported fossil fuels as such. They have steadily increased from 2.5 tonnes per capita (1983) to 3.4 tonnes per capita (1997), similar to the weight of the imported fossil fuels as such.

The "hidden flows" associated with the domestic extraction of fossil fuels are much higher than the used extraction. During the 1980ies, the unused extraction associated with the domestic extraction of fossil fuels amounted to some 4 to 4.5 billion tonnes (around 12 tonnes per capita) which was about five times more than the used part. This huge "hidden" component was due to the extraction of lignite and hard coal which induce high unused extraction per unit of usable raw material. The specific ratio for "hidden flows" to used (marketed) extraction for hard coal can range from 0.3 to more than 6.2 tonnes per tonne (Bringezu and Schütz 2001, p. 77). For lignite, the specific ratios even range from 5.0 to 11.6 tonnes per tonne.

In the early 1990ies, the domestic "hidden flows" of domestically extracted fossil fuels decreased dramatically due to decreasing extraction of lignite, particularly in Germany. The extraordinary importance of lignite and hard coal is also revealed when looking at the composition of the TMR of fossil fuels (Figure 4-18). About three fourths of the TMR of fossil fuels is determined by lignite and hard coal. Only one fourth is due to other energy carriers (oil, gas, others) and imported electricity.

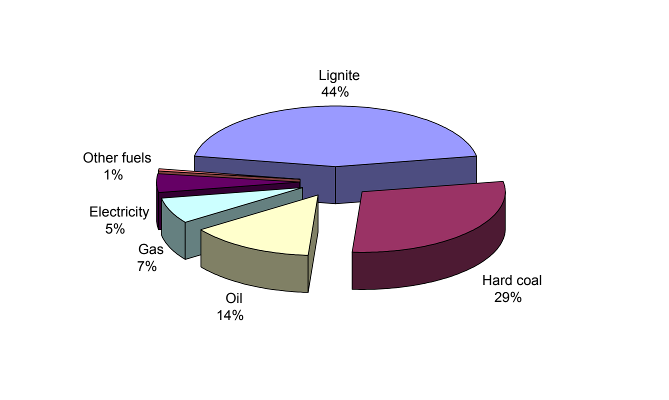


Figure 4-18: Composition of TMR of fossil fuels – EU-15, 1997

Source: Eurostat & Wuppertal Institute (2001), data set A

Looking at the "resource efficiency" of primary energy supply, it shows that the TMR of fossil fuels has de-coupled from the primary energy supply since the early 1990ies (Figure 4-19). This de-coupling seems to be a consequence of the changed energy-mix, i.e. the shift from domestic lignite and hard coal towards imported oil and natural gas.

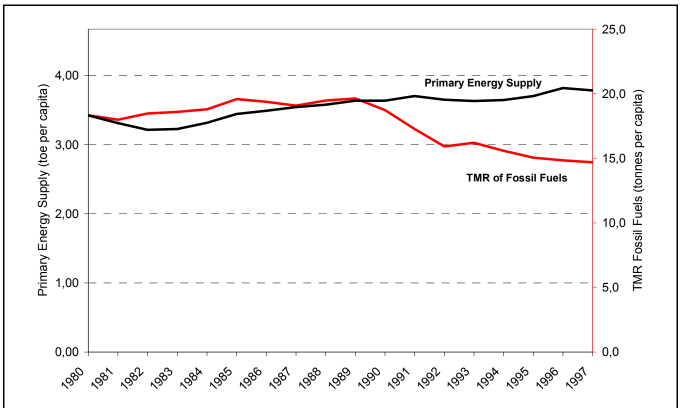


Figure 4-19: De-coupling of TMR of fossil fuels from Primary Energy Supply – EU-15, 1980-1997

Source: Eurostat & Wuppertal Institute (2001), data set A; and IEA

4.3. Metals and industrial minerals

Metal ores and industrial minerals account for about 9% of the materials directly used and processed within the EU, i.e. the Direct Material Input (DMI). However, when considering the life-cycle-wide resource requirements associated with metals and industrial minerals, i.e. their "hidden flows", the share increases significantly. They account for one fourth of the Total Material Requirement (TMR) of the EU. This indicates already that the "hidden flows" associated with metals and industrial minerals are very high.

Within the EU (Table 4-3), the directly used domestic extraction of metal ores and industrial minerals continuously decreased throughout the 1980ies and 1990ies from about 240 to about 150 million tonnes (680 to 400 kg per capita respectively). On the other hand, imports of metals and industrial minerals continuously increased from about 250 to almost 400 million tonnes (0.71 to 1.05 tonnes per capita respectively). This pattern clearly reveals a shift from domestic extraction towards the import of metals and industrial minerals.

Domestic extractions directly used and imports add up to the DMI of metals and industrial minerals. The latter decreased in the 1980ies from 492 to 469 million tonnes (1.39 to 1.29 t/cap respectively). After the economic recession in the early 1990ies, it recovered again and increased to 549 million tonnes in 2000 (1.46 t/cap respectively).

The exports of metal and industrial minerals based goods followed a similar pattern. With slightly less than one tonne per capita, the Direct Material Consumption (DMC), i.e. the apparent consumption within the EU, was in the same order of magnitude at the beginning and the end of the observation period. In between it had been below that level. All in all, the metal and industrial mineral figures have been fairly fluctuating, indicating a close relationship with economic development cycles. The latter applies in particular to the trade figures.

Table 4-3: Metal ores and industrial minerals – Direct material input and consumption accounts, EU-15, 1980-2000

		1980	1985	1990	1995	2000
		1000 tonnes				
	Domestic extraction used (DE)	240 421	213 502	185 721	161 525	152 117
+	Imports	252 005	259 547	283 436	338 105	396 877
=	DMI	492 426	473 048	469 157	499 630	548 995
−	Exports	144 936	158 973	134 824	151 261	170 696
=	DMC	347 490	314 075	334 333	348 370	378 299
		tonnes per capita				
	Domestic extraction used (DE)	0.68	0.60	0.51	0.43	0.40
+	Imports	0.71	0.72	0.78	0.91	1.05
=	DMI	1.39	1.32	1.29	1.35	1.46
−	Exports	0.41	0.44	0.37	0.41	0.45
=	DMC	0.98	0.88	0.92	0.94	1.00
		% of DMI				
	Domestic extraction used (DE)	69	68	56	46	40
+	Imports	73	83	85	97	105
=	DMI	142	151	140	143	145
−	Exports	42	51	40	43	45
=	DMC	100	100	100	100	100

Source: Eurostat & IFF (2002), data set B

Note: imports and exports include all traded raw materials, semi-manufactures and final goods attributable to the materials category "metals and industrial minerals"; only extra-EU trade.

Domestic extraction of metals is composed differently to imports of metals (Figure 4-20 and Figure 4-21).

Domestic extraction of metals is dominated by copper (35%) and iron (26%). Silver (13%), Zinc (10%), and Gold (6%) form further quantitatively important components of EU domestic metal extraction.

Imports of metals are clearly dominated by iron which accounts for three fourths of all metal imports. Only aluminium (8%), zinc (2%) and copper (2%) play also a quantitative role.

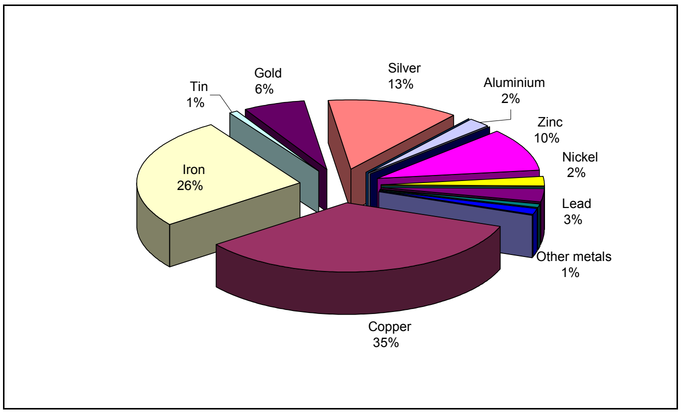


Figure 4-20: Composition of domestically extracted metals – EU-15, 1997

Source: Eurostat & Wuppertal Institute (2001), data set A

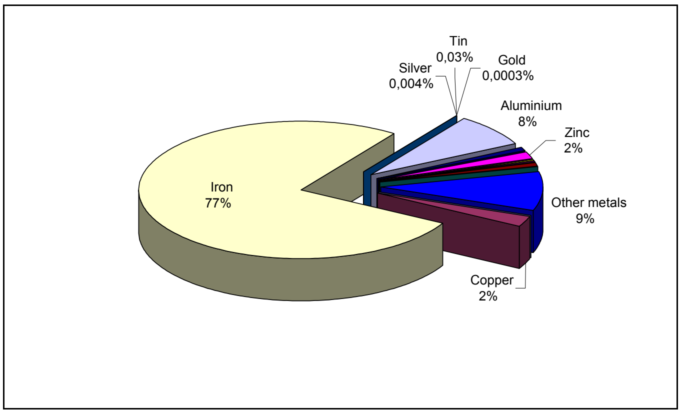


Figure 4-21: Composition of imported metals – EU-15, 1997

Source: Eurostat & Wuppertal Institute (2001), data set A

Domestic extraction of industrial minerals (Figure 4-22) is dominated by industrial sands (40%) and salt (27%). Imports (Figure 4-23) of industrial minerals are dominated by phosphate (33%) and industrial clays (18%).

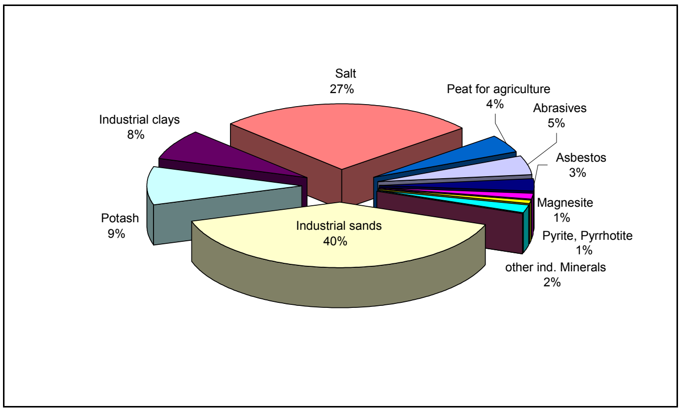


Figure 4-22: Composition of domestically extracted industrial minerals – EU-15, 1997

Source: Eurostat & Wuppertal Institute (2001), data set A

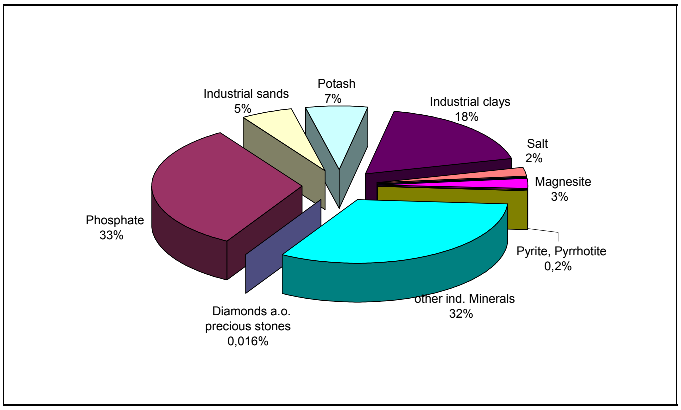


Figure 4-23: Composition of imported industrial minerals – EU-15, 1997

Source: Eurostat & Wuppertal Institute (2001), data set A

Considering also the life-cycle-wide resource requirements, i.e. the "hidden flows", reveals a different picture for metals and industrial minerals. As already mentioned at the beginning of this section, metals and industrial minerals have significantly high "hidden" components (see Table 4-4).

Table 4-4: Hidden Flows ratios (tonnes per tonne) for selected metals and industrial minerals

	domestic	imported		domestic	imported
Metals:			**Industrial minerals:**		
Precious metals (ores and concentrates not further specified)	-	60 007	Diamonds a. o. precious stones	-	46 427
Copper	1.0	151	Phosphate	-	5.8
Iron	0.6	2.3	Industrial sands	0.0	0.3
Tin	0.1	6 479	Potash	1.7	7.5
Gold	0.1	590 711	Industrial clays	2.0	0.8
Silver	1.3	12 175	Salt	0.0	1.3
Platinum		413 307	Peat for agriculture	0.3	-
Aluminium (Bauxite)	12.9	1.7	Asbestos	0.1	0.2
Titanum		45.9	Magnesite	0.0	0.2
Zinc	0.1	8.4	Pyrite, Pyrrhotite	0.0	0.7
Nickel	0.1	43.0			
Molybdenum	-	223			
Lead	0.2	12.6			

Source: Eurostat & Wuppertal Institute (2001), data set A

In particular, imported metals and industrial minerals are associated with higher "hidden flows" than the domestically extracted ones. Since the domestic extraction decreased on the account of imports, the overall TMR of metals and industrial minerals has been significantly increasing throughout the observation period.
The following graphs show the development of TMR for metals (Figure 4-24) and industrial minerals (Figure 4-25), illustrating the asymmetric distribution of domestic (grey bars) and foreign (orange bars) components.

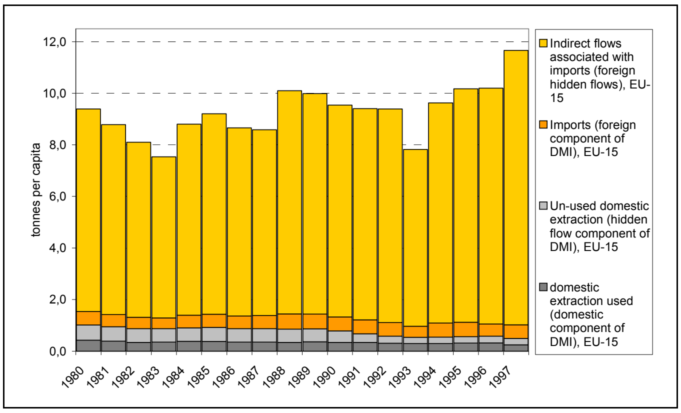


Figure 4-24: TMR of metals – EU-15, 1980-1997

Source: Eurostat & Wuppertal Institute (2001), data set A

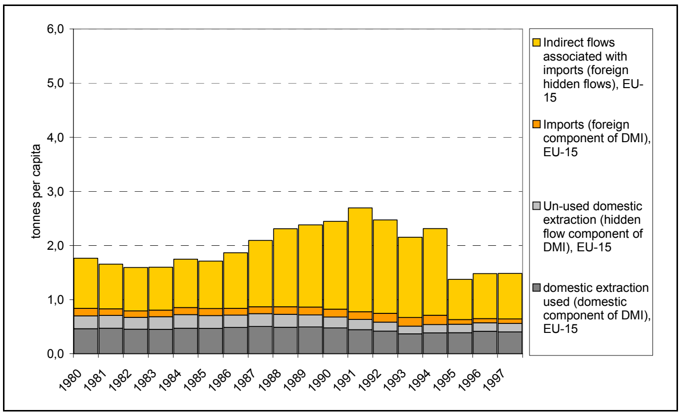


Figure 4-25: TMR of industrial minerals – EU-15, 1980-1997

Source: Eurostat & Wuppertal Institute (2001), data set A

The following two graphs show internal composition of the TMR of metals and industrial minerals.
TMR of metals (Figure 4-26) is dominated by precious metals such as gold, silver and platinum group metals accounting for more than 50%. Copper is with some 18% the second important component, followed by iron with some 12% and tin with some 10%.

TMR of industrial minerals (Figure 4-27) is dominated by diamonds and precious stones with some 43%. Other important components are phosphate (12%), industrial sands (11%), potash (10%), industrial clays (8%) and salt (8%).

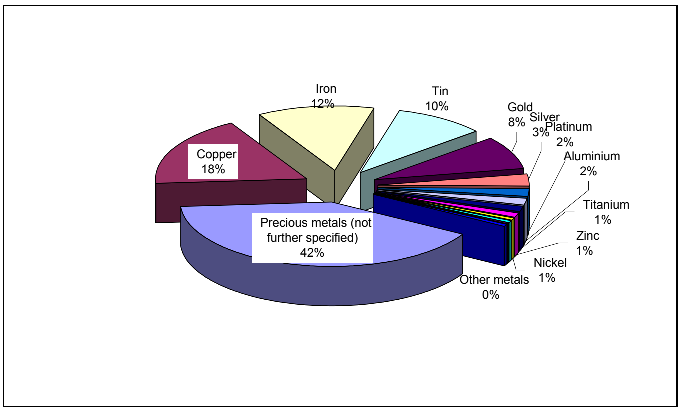


Figure 4-26: Composition of TMR of metals – EU-15, 1997

Source: Eurostat & Wuppertal Institute (2001), data set A

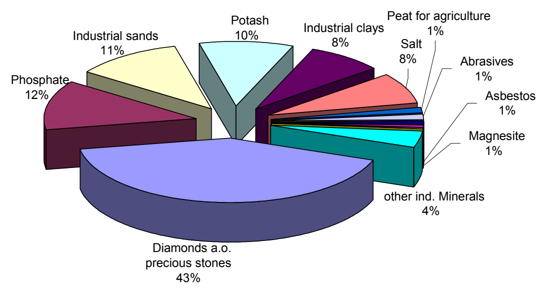


Figure 4-27: Composition of TMR of industrial minerals – EU-15, 1997

Source: Eurostat & Wuppertal Institute (2001), data set A

4.4. Construction minerals

Construction minerals constitute a further mass resource flow. About 40% of the Direct Material Input (DMI), i.e. materials directly used and processed, to the EU economy is formed by construction minerals. Its share to the Total Material Requirement (TMR) is however only 18%, indicating that construction minerals play a minor role with regards to life-cycle-wide "hidden flows".

Construction minerals are mainly domestically extracted within the EU (Table 4-5). During the 1980ies, around 2.5 billion tonnes of construction minerals were extracted domestically each year (about 6.5 to 7 tonnes per capita respectively). At the turn of the decade, the demand for construction minerals increased slightly to more than 2.7 billion tonnes (partly due to German reunification and the resulting activity increase in the construction sector) and remained more or less on a slightly higher level throughout the 1990ies. On a per capita basis the use of construction minerals amounted to about 7 t/cap at the end of the observation period, almost the same figure as in 1980.

The majority of this material is accumulating in the physical stock of the EU economy in terms of new buildings and infrastructures, contributing to a physical net growth (see section 4.7 on NAS).

Table 4-5: Construction Minerals – Direct material input and consumption accounts, EU-15, 1980-2000

		1980	1985	1990	1995	2000
		1000 tonnes				
	Domestic extraction used (DE)	2 475 432	2 340 253	2 703 102	2 666 231	2 583 829
+	Imports	0	0	0	0	0
=	DMI	2 475 432	2 340 253	2 703 102	2 666 231	2 583 829
−	Exports	0	0	0	0	0
=	DMC	2 475 432	2 340 253	2 703 102	2 666 231	2 583 829
		tonnes per capita				
	Domestic extraction used (DE) = DMI = DMC	6.98	6.53	7.43	7.18	6.86

Source: Eurostat & IFF (2002), data set B

Note: Imports and exports are zero since it is assumed (dtat set B) that construction minerals in trade flows are small, all mineral trade flows are allocated to the category "industrial minerals and metal ores".

Considering the “hidden flows” associated with construction minerals does not change the picture very much (Figure 4-28). Firstly, the domestic “hidden flows” associated with the extraction of construction minerals are relatively small. Secondly, there are no relevant imports and hence no associated foreign “hidden flows”. However, one can attribute the “hidden flow” category of soil excavation and dredging to the construction minerals since these are closely linked to construction activities.
The composition of the TMR of construction minerals (Figure 4-29) is dominated by natural stones (31%) and sand and gravel (25%). Limestone accounts for a further 16% and clays form 2%. About one fourth is constituted by excavation (21%) and dredging (5%).

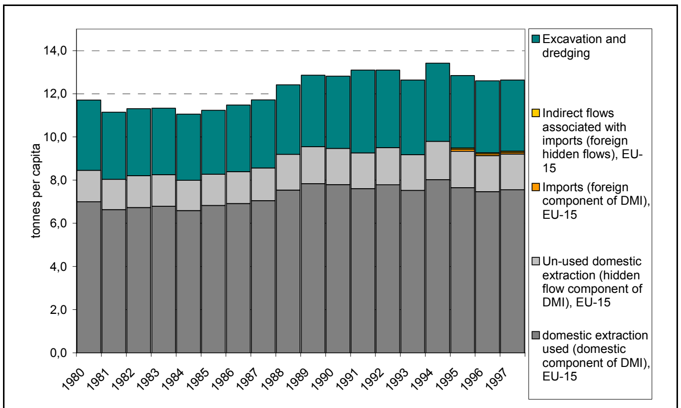


Figure 4-28: TMR of construction minerals – EU-15, 1980-1997

Source: Eurostat & Wuppertal Institute (2001), data set A

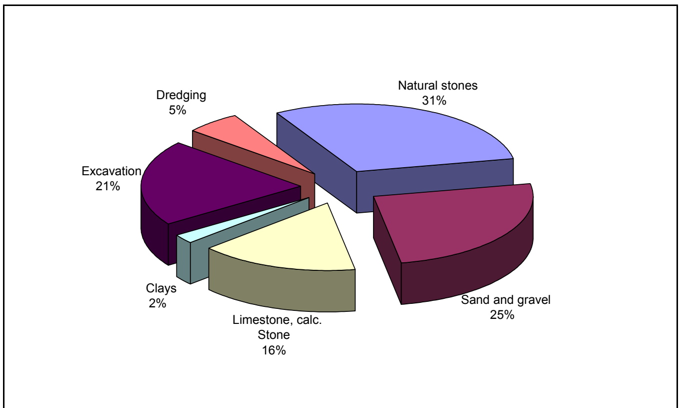


Figure 4-29: Composition of TMR of construction minerals – EU-15, 1997

Source: Eurostat & Wuppertal Institute (2001), data set A

4.5. Biomass

About one fourth (26%) of the Direct Material Input (DMI) to the EU economy is formed by renewable biomass. The share of biomass and erosion – constituting the non-renewable “hidden flows” of imported biomass – to the Total Material Requirement is about 21%. Biomass demand of the EU is mainly met by domestic extraction (self-sufficiency rate of about 95%).

Within the EU, domestic extraction of biomass increased during the early 1980ies from 1.3 to 1.4 billion tonnes (about 3.7 to 3.9 t/cap respectively). In the early 1990ies it dropped to almost 1.3 billion tonnes and returned to a level above 1.4 billion tonnes in the late 1990ies. Imports of biomass into the EU amounted to around 150 to 160 million tonnes during the 1980ies. Although imports significantly fluctuated during the 1990ies, an increasing trend could be observed. At the end of the 1990ies, biomass imports to the EU amounted to more than 180 million tonnes (0.5 t/cap respectively).

DMI of biomass slightly increased during the 1980ies from 1.5 to almost 1.6 billion tonnes, dropped at the beginning of the 1990ies and increased again at the end of the 1990ies to more than 1.6 billion tonnes (4.3 t/cap respectively).

This development was partly mirrored by the exports of biomass. However, in general, exports of biomass based goods showed a clearly increasing trend from 63 to 112 million tonnes over the observation period (0.2 to 0.3 t/cap respectively).

The apparent consumption of biomass in the EU, i.e. the Direct Material Consumption (DMC), remained rather constant on a per capita basis over the period with some 4 t/cap.

Table 4-6: Biomass – Direct material input and consumption accounts, EU-15, 1980-2000

		1980	1985	1990	1995	2000
		1000 tonnes				
	Domestic extraction used (DE)	1 330 510	1 406 146	1 403 217	1 328 754	1 439 579
+	Imports	162 696	157 051	170 717	170 535	186 400
=	DMI	1 493 205	1 563 197	1 573 934	1 499 289	1 625 979
−	Exports	62 965	80 771	93 767	91 742	111 993
=	DMC	1 430 240	1 482 426	1 480 167	1 407 547	1 513 986
		tonnes per capita				
	Domestic extraction used (DE)	3.75	3.92	3.86	3.58	3.82
+	Imports	0.46	0.44	0.47	0.46	0.50
=	DMI	4.21	4.36	4.33	4.04	4.32
−	Exports	0.18	0.23	0.26	0.25	0.30
=	DMC	4.03	4.14	4.07	3.79	4.02
		% of DMI				
	Domestic extraction used (DE)	93	95	95	94	95
+	Imports	11	11	12	12	12
=	DMI	104	105	106	107	107
−	Exports	4	5	6	7	7
=	DMC	100	100	100	100	100

Source: Eurostat & IFF (2002), data set B

Note: imports and exports include all traded raw materials, semi-manufactures and final goods attributable to the materials category "biomass"; only extra-EU trade.

If one considers the "hidden flows" associated with the domestic extraction and imports of biomass, the picture changes with regards to erosion forming the "hidden flows" of biomass (Figure 4-30). With some 4.5 tonnes per capita, erosion has been fairly constant throughout the observation period.

The domestic harvested and imported biomass is dominated by biomass from agriculture which forms about 87% (Figure 4-31). About 12% of biomass comes from forestry and only 1% is attributable to fishery, hunting and wild harvest.

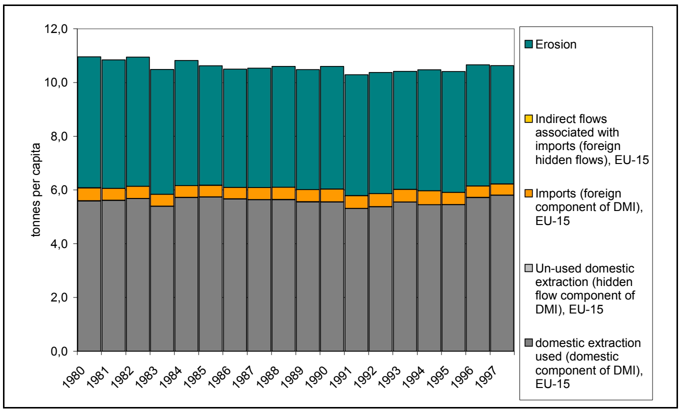


Figure 4-30: TMR of biomass – EU-15, 1980-1997

Source: Eurostat & Wuppertal Institute (2001), data set A

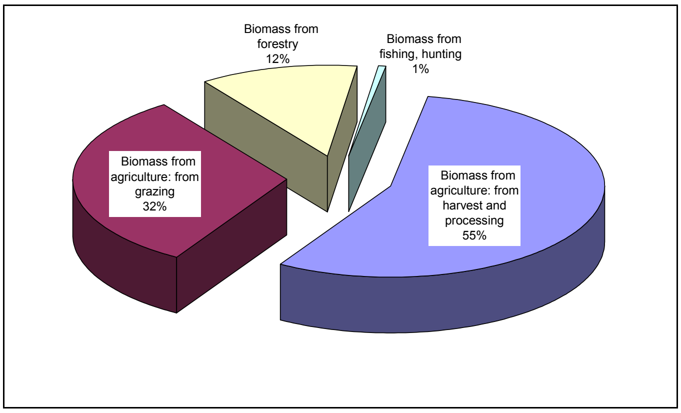


Figure 4-31: Composition of TMR of biomass (without erosion) – EU-15, 1997

Source: Eurostat & Wuppertal Institute (2001), data set A

4.6. Total outputs, waste streams and principal emissions to the environment

Domestic processed output (DPO), i.e. flows of no longer used materials leaving the EU economy in the form of emissions to air, water and land, amounted to around 4.4 billion tonnes or 12 tonnes per capita in 1996. This is only about one fourth of the Total Material Requirement (TMR) and about two thirds of the Direct Material Input (DMI) entering processing in the EU economy.

With some 10 tonnes per capita, DPO is dominated by air emissions (more than 80%). Within the air emissions category, CO_2 is responsible for the majority.
About 2 tonnes per capita are residual flows to land, of which landfilled wastes form the main part (about 1.2 tonnes per capita). Emissions to water (accounted for without water) only form a minor part with about 40 kg per capita (minimum estimate).

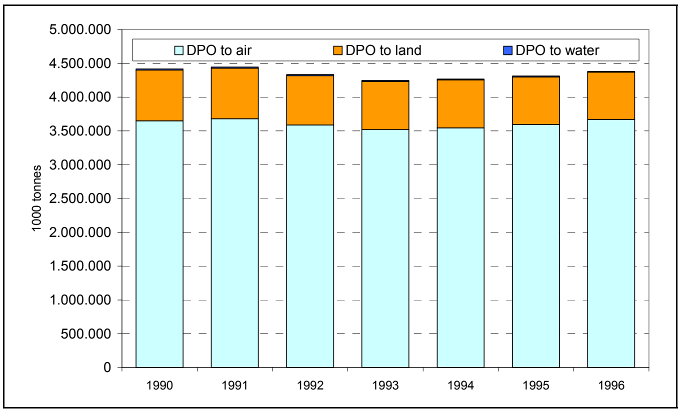


Figure 4-32: Domestic Processed Output by three main categories, EU 1990-1996 – absolute (1000 tonnes)

Source: Eurostat & Wuppertal Institute (2001), data set A

4.7. Physical growth of the EU economy (net additions to stock) including impacts on land use

Net additions to stock, i.e. the annual net growth of the physical economy, amounted to about 10 tonnes per capita in the first half and middle of the 1990ies.

The physical growth of the EU economy is of concern for two major reasons. First, it is related to future waste generation. The management of the physical stock as a source for secondary raw materials constitutes a growing challenge. Second, NAS is closely linked to the continuous expansion of built-up area in the European Union – a rising environmental policy issue.

"Over the past 20 years the extent of built-up area in many western and eastern European countries has increased by some 20 % and far exceeds the rate of population growth in the EU over the same period (6 %)" (EEA: Environmental Signals 2002). However, on a European level precise statistical information on built-up area is lacking. In Germany, the annual NAS has been around 10 tonnes per capita and is accompanied by an annual increase of built-up area of around 450 km^2 (i.e. almost 15 m^2 per second). This average value of the 1990ies has even been increasing since 1999. As a consequence of the expansion of built-up land, the available land for reproduction of biomass in agriculture and forestry and for nature conservation is continuously being diminished. This depletion of domestic capacities will successively increase the dependence of the EU on external supply. The trend of physical growth is characterised by a significant steadiness and may not be changed by short-term policies.

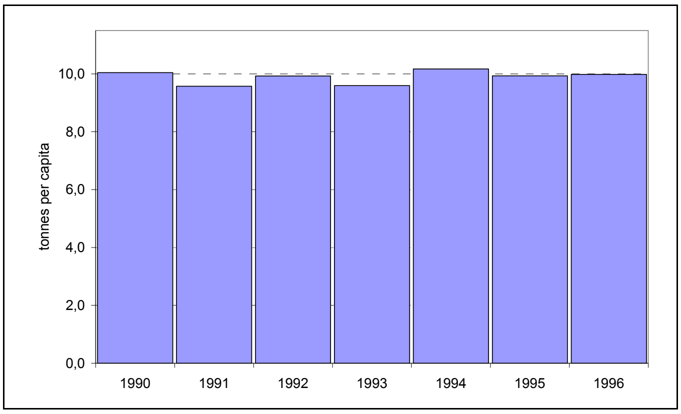


Figure 4-33: Net Additions to Stock (NAS), EU 1990-1996. per capita tonnes

Source: Eurostat & Wuppertal Institute (2001), data set A

4.8. De-coupling, macro-economic resource productivities

With the exception of a recession in 1993, the EU-15 economy steadily grew from around 12 000 Euro per capita (constant 1990 prices) in the early 1980ies to more than 16 000 Euro in the second half of the 1990ies. At the same time, resource use in the form of TMR kept fairly constant at around a level of 50 tonnes per capita.

This relative de-coupling of economic growth on the one hand and resource requirements on the other hand has led to an increase in resource productivity (GDP per TMR) by 39% between 1980 and 1997. Whereas in 1980 222 Euro of GDP (in constant 1990 prices) was generated per one tonne TMR, this ratio was 309 Euro/kg in 1997.

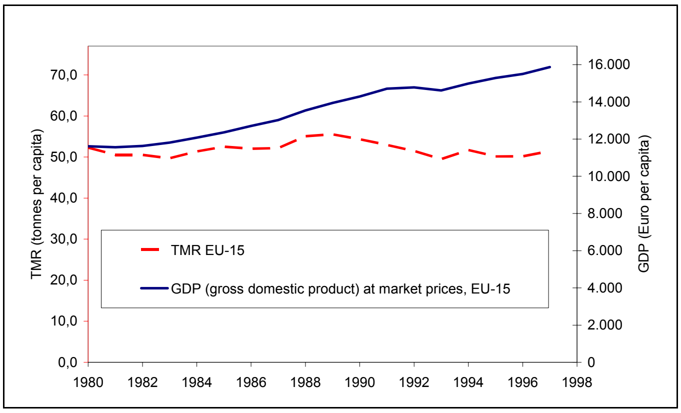


Figure 4-34: TMR and GDP per capita, EU 1980-1997

Source: Eurostat & Wuppertal Institute (2001), data set A

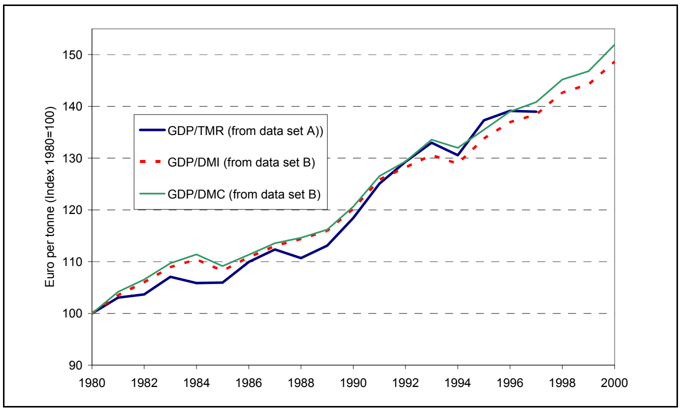


Figure 4-35: Different resource productivities, EU 1980-2000, index 1980=100

Source: Eurostat & Wuppertal Institute (2001), data set A; and Eurostat & IFF (2002), data set B

Resource productivity measured as GDP per DMI increased by 49% between 1980 and 2000 from 800 to 1189 Euro per tonne DMI. Resource productivity measured as GDP per DMC increased by 52% from 838 to 1274 Euro per tonne DMC. All in all, the resource productivities measured with the different material aggregates developed fairly similarly.

Direct resource productivity of the EU's economy – measured as GDP per tonne Direct Material Input (DMI) – almost reached 1200 Euro/tonne in the year 2000 and increased at an average annual growth rate of around 2% over the period 1980-2000. In other words, DMI of the EU economy has been de-coupling from economic growth (relatively) over the past two decades.

Direct resource productivity also varies considerably across countries. The lowest value can be found in Greece with some 557 Euro per tonne, the highest in France with 1232 Euro per tonne direct material input.

If we relate the GDP to the direct material consumption (DMC, i.e. DMI minus exports), a somewhat different picture appears. First, the productivity for the EU increases to 1274 Euro per tonne DMC. In particular the comparably small economies such as Belgium/Luxemburg, Denmark, or Netherlands, but also big export based economies such as Germany and France, have much higher resource productivities if one considers the DMC to build the ratio.

Table 4-7: Resource productivities of EU Member States, 2000

Country	GDP*/DMI Euro/tonne	GDP*/DMC Euro/tonne
Netherlands	909	1847
France	1232	1505
Belgium/Luxembourg	705	1474
United Kingdom	1125	1445
Germany	1183	1404
Austria	1107	1395
Denmark	957	1299
Italy	1091	1270
Sweden	848	1123
Ireland	809	914
Spain	709	810
Finland	581	692
Portugal	621	687
Greece	557	634
EU-15	**1189**	**1274**

* Note: GDP in constant 1995 prices
Source: Eurostat & IFF (2002), data set B

4.9. On the sectoral attribution of resource flows

Sectoral attribution of resource flows is useful for policy making as it allows identification of potential addressees of concrete policy measures in the field of sustainable resource management.

However, there is no definite way of attributing any material flow to a certain sector. One can attribute a certain resource – e.g. hard coal – to the mining company which has actually been extracting the particular resource. One can also attribute a certain resource to the user. In the case of hard coal, this could be a power plant combusting the hard coal in order to generate electricity. Finally, one could also argue that the end-user of that electricity is responsible for the extraction of that particular hard coal, e.g. private households or an industry such as manufacturing of motor vehicles. With regards to the latter, one could again argue that the end-user, i.e. the private household purchasing a car, is responsible for the electricity required by the manufacturer, and so on. In the end, everything is produced for final consumption and no consumption would ever be possible without production. And, attribution gets even more complicated in the case of imports.

In general, resources can be attributed to
a) the resource extracting sector (e.g. mining, agriculture etc.),
b) an intermediate user (e.g. all manufacturing industries), or
c) the final consumer or end-user (e.g. private households).

Based on the available data set, only the first kind of attribution (case a) is feasible and results will be presented and discussed in the following.

For the other two broad options of attribution (cases b and c), input-output technologies have to be applied which again require extensive data, namely monetary and physical input-output tables (see for example Moll et al. 1999, Behrensmeier/Bringezu 1995).

4.9.1. Sectoral attribution of domestically extracted resources

Materials domestically extracted within the territory of the European Union – be it used or non-used – can be attributed to those economic sectors (branches) which have actually been extracting or harvesting the materials.

The "statistical classification of economic activities in the European Community" (NACE Rev.1) has been used which distinguishes 60 divisions on the 2-digit-code level.
The sectoral attribution is simply done on the basis of the materials' characteristics. For instance, biomass harvest can be simply attributed to the agriculture, forestry and fishing branch.

The following two graphs show for the year 1999 the used domestic extraction of materials and the unused domestic extraction of materials, i.e. domestic hidden flows, by the extracting NACE branches for the EU and the year 1999.

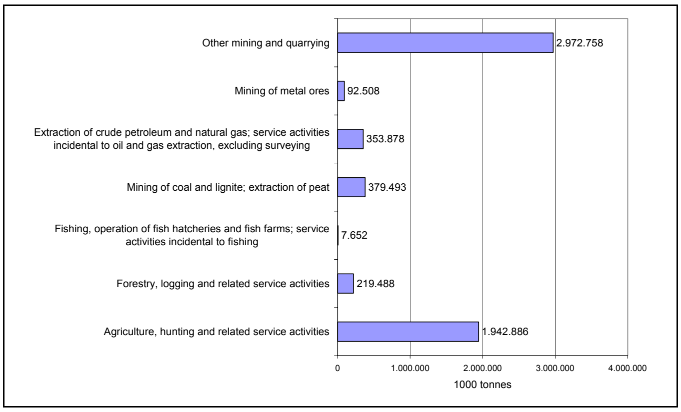


Figure 4-36: Domestic extraction used, by extracting NACE branches – EU 15, 1999

Source: Eurostat & Wuppertal Institute (2001), data set A

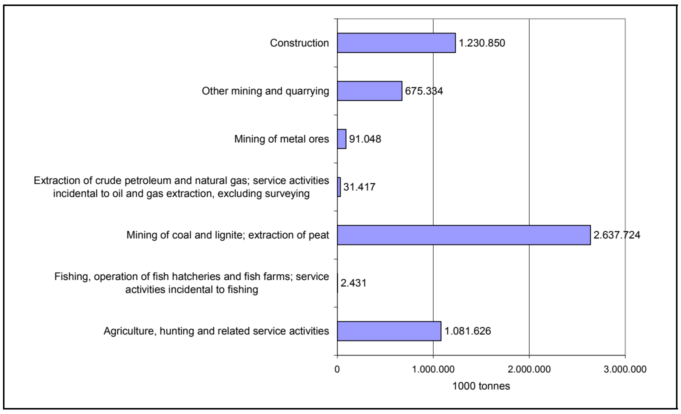


Figure 4-37: Unused domestic extraction, by extracting NACE branches – EU 15, 1999

Source: Eurostat & Wuppertal Institute (2001), data set A;

Both figures show that the domestic extraction of material is limited to a small number of economic branches. Biomass is extracted by the so-called primary sectors, i.e. agriculture, forestry and fisheries. Minerals and fossil fuels are extracted by the mining industries, whereby the extraction of coal and lignite has a huge unused fraction. The construction sector is responsible for another huge “hidden flow”, i.e. the excavation for buildings and infrastructures.

In the course of future development towards a more sustainable supply, use and waste management of resources, those sectors will be especially challenged. Agriculture and forestry will have to improve the quality of the cultivation schemes in order to reduce environmental burden (an aspect not reflected in the quantitative accounts provided here). Together with fisheries, these sectors will have to accommodate towards the reproductive capacities of natural processes. The mining of fossil fuels will have to be reduced significantly, especially for reasons of climate stability. If the extraction of other non-renewables is gradually but continually reduced, then industries may proceed to develop the spectrum of their products, e.g. through increased production of recycled materials. They will have to adjust at least to the ongoing development, which is characterised by the trend towards increased direct resource productivity. The manufacturing and consuming sectors of the economy are already using less primary materials per unit of value added. It will be interesting to see the results of further analysis on how far the different manufacturing sectors are proceeding towards this end.

4.9.2. Attribution of foreign material inputs (imports and associated hidden flows)

Based on the available data, imports (and their associated hidden flows) into the EU can only be grouped into commodity groups. For this, again the NACE classification has been used. It has to be made very clear that the imports (and their associated hidden flows) cannot be attributed to the receiving economic sectors since this would require much more statistical information (at least monetary input-output tables with import matrices).

The following two graphs show the imports as such and their associated hidden flows by commodity groups, compatible to the 60 divisions of the NACE classification.
Imports are dominated by commodities from the extraction of crude petroleum and natural gas. Other important imports are coal and coal products as well as metal ores.
The main “hidden flows” are associated to the imports of metal based commodities.

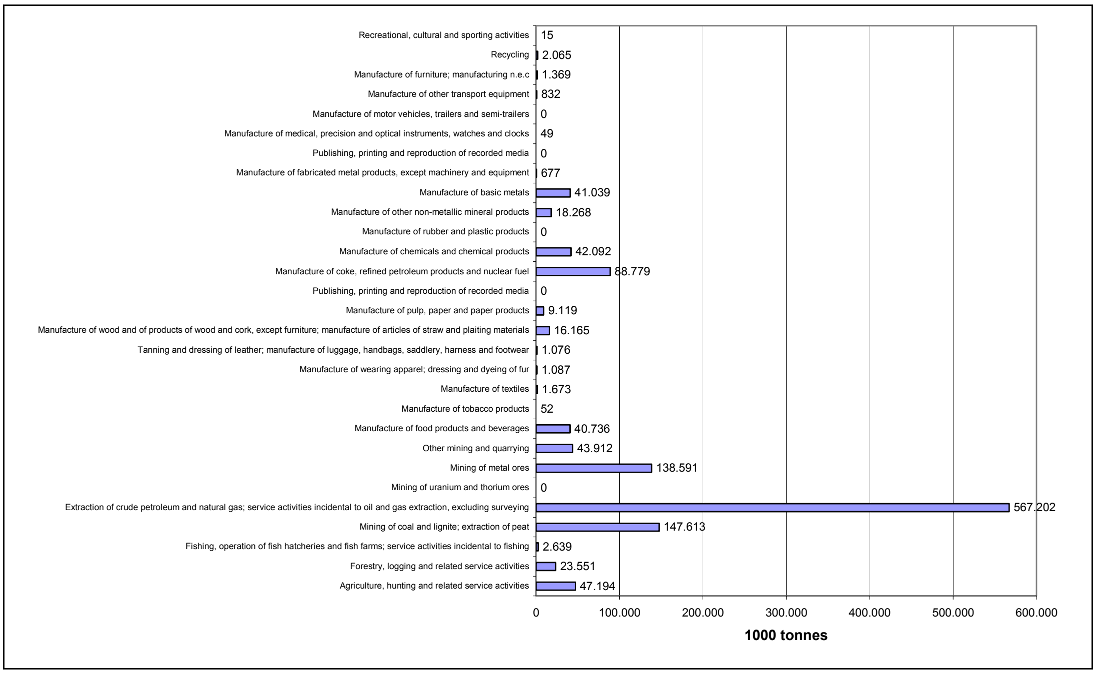


Figure 4-38: Imports, by commodity groups according to NACE – EU 15, 1999

Source: Eurostat & Wuppertal Institute (2001), data set A

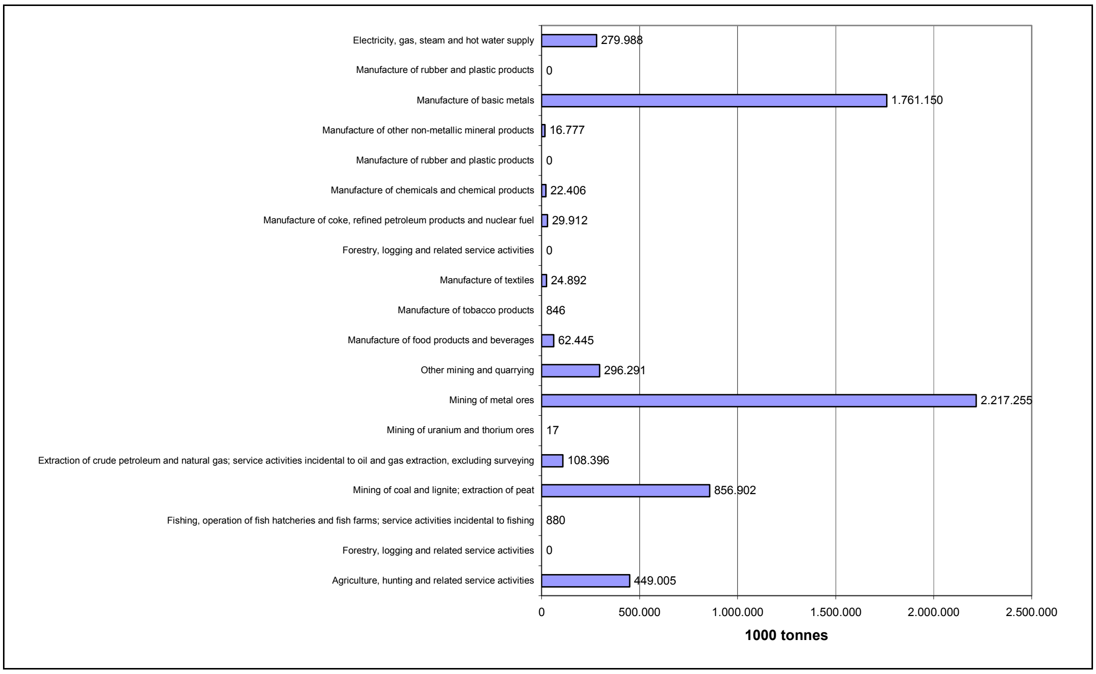


Figure 4-39: Hidden flows associated with imports, by commodity groups according to NACE – EU 15, 1999

Source: Eurostat & Wuppertal Institute (2001), data set A;

5. Material Flow Accounts for EU-Accession Countries

This chapter presents most recent MFA data for the 13 EU Accession Countries. Data have been compiled by the Wuppertal Institute in a separate project for the ETC/WMF and are referred to as *data set C* (Schütz 2002). Due to statistical data availability, time series comprise only the domestic extraction and imports (which can be aggregated to the DMI indicator) for the period of 1992 to 1999.

Main findings for Accession Countries are the following:

- Materials use in terms of DMI is on a significantly lower level than EU's DMI and rose slightly throughout the 1990ies.
- DMI has also de-coupled relatively from economic growth.
- The renewable share of DMI (i.e. biomass) is higher than in the EU.
- Resource productivity (GDP per tonne DMI) is lower in Accession Countries by a factor 5. It will require extraordinary efforts to achieve EU levels of resource productivity.
- Imports of materials show an increasing trend.

5.1. Overview – Direct Material Input (DMI) for the EU Accession Countries (AC-13)

Ranging between 1.8 to 2.0 billion tonnes, Direct Material Input (DMI) of Accession Countries showed a slightly increasing trend during the 1990ies (Figure 5-1). On a per capita basis, the aggregated DMI of these countries ranged between 10.7 and 11.8 tonnes per capita.

The DMI of AC is dominated by biomass, accounting for about 40%, and fossil fuels, representing about one third. Whereas the share of fossil fuels fell, that of biomass rose slightly during the 1990ies. Hence, the share of non-renewable resources to DMI deceased slightly from 63% in 1992 to 60% in 1999.

Another approx. 25% of DMI is formed by minerals, i.e. metals, industrial and construction minerals. However, data have to be interpreted with caution due to statistical restrictions, in particular with regards to construction minerals.

Imports of semi-manufactured and final goods which cannot be attributed to one of the above three categories constitute another 2% of DMI.

As in the EU, DMI of Accession countries relatively de-coupled from economic growth during the 1990ies (Figure 5-2).

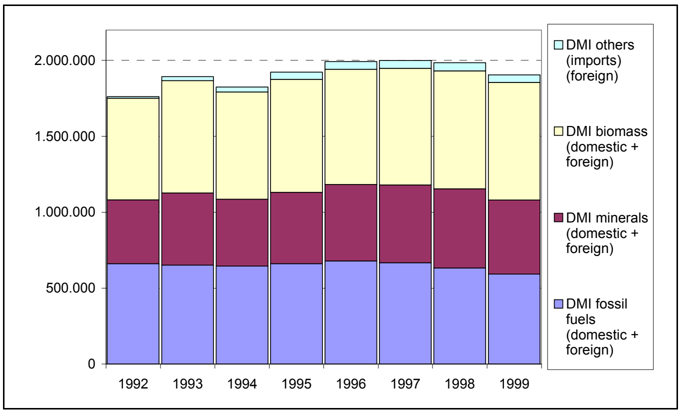


Figure 5-1: DMI by main material categories, AC-13 1992-1999, in 1000 tonnes

Source: Wuppertal Institute (2002), data set C

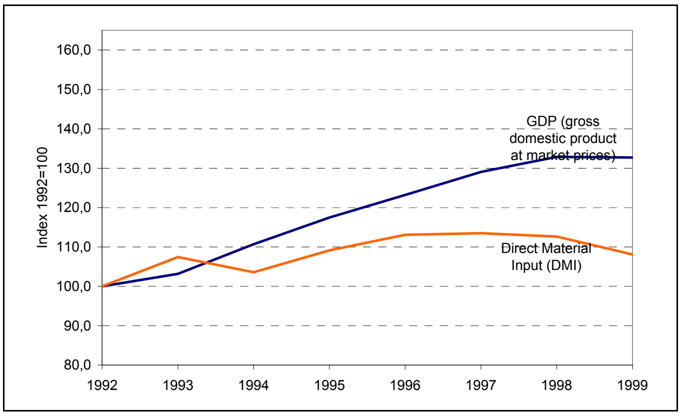


Figure 5-2: De-coupling of DMI from economic growth, AC-13 1992-1999

Source: Wuppertal Institute (2002), data set C

DMI of the single Accession Countries vary considerably (Figure 5-3). Some countries reached much higher values than the average, such as Cyprus and Estonia with around 25 and 40 tonnes per capita respectively. Other Accession Countries are significantly below the average, such as e.g. Turkey.

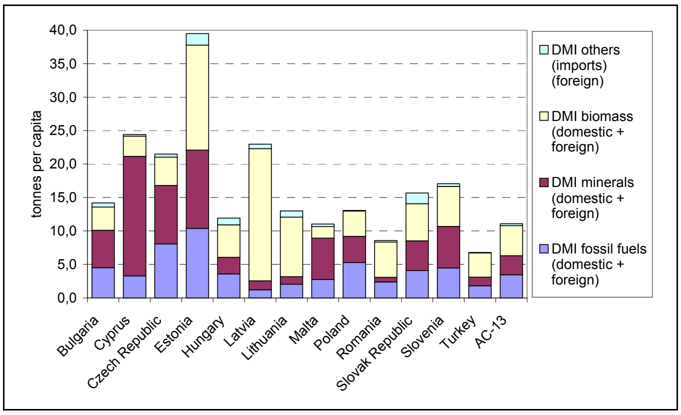


Figure 5-3: DMI by countries, 1999

Source: Wuppertal Institute (2002), data set C

5.2. Domestic extraction of used raw materials (fossil fuels, minerals, and biomass)

Domestic extraction of fossil fuels in the Accession Countries decreased from around 500 million tonnes in 1992 to about 416 million tonnes in 1999 (Figure 5-4). On a per capita basis this was a decrease from 3.0 to 2.4 tonnes per capita. This is more than in the EU, where fossil fuel extraction declined from 2.1 to 1.9 tonnes per capita during the same time period.

Lignite has been the dominant fuel extracted domestically in the 13 countries, accounting for about 60% throughout the observation period. In absolute terms, lignite extraction declined from 298 to 253 million tonnes in the Accession Countries.
Hard coal has also declined from around 159 million tonnes to almost 128 million tonnes in 1999, constituting a share of 31% then. Oil extraction remained rather constant at around 12 million tonnes which is 3% of fossil fuel extraction in Accession Countries. Extraction of gas declined from 29.5 to 22 million tonnes, representing 5% of fossil fuel extraction in Accession Countries.

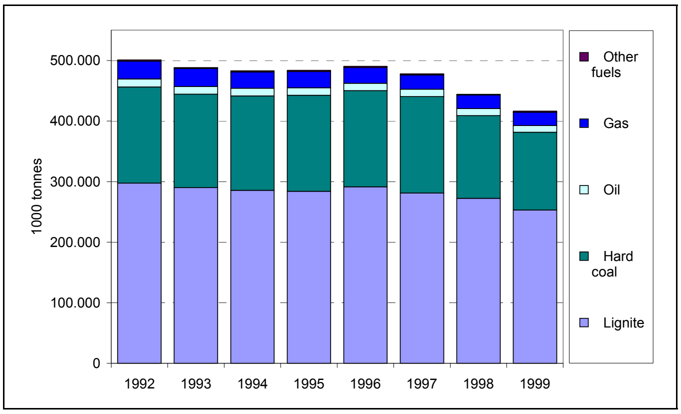


Figure 5-4: Domestic extraction of fossil fuels by fuel categories, AC-13 1992-1999, in 1000 tonnes

Source: Wuppertal Institute (2002), data set C

Domestic extraction of minerals has been fluctuating around 450 million tonnes (22% of total DMI), ranging from 415 million tonnes (1994) to 485 million tonnes (1998). Due to data restrictions, only the aggregated minerals (comprising metals, industrial and construction minerals) can be shown. No further disaggregation is feasible.

Domestic harvest of biomass in the 13 Accession Countries increased from about 646 million tonnes in 1992 to more than 730 million tonnes in 1999 (Figure 5-5). On a per capita basis, this is an increase from 3.9 to 4.3 tonnes per capita.

More than half of domestic biomass stems from agricultural harvest and processing (53% in 1999). About one fourth stems from grazing. Forestry harvest increased significantly from 102 to 150 million tonnes, increasing its share from 16% to 20%. Fishing and hunting only contribute with one per cent and play a minor role.

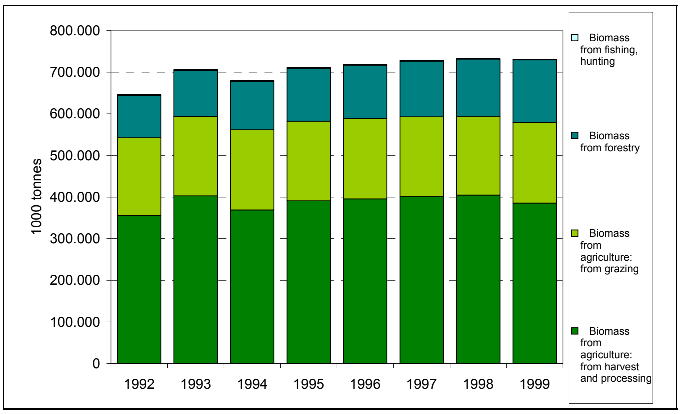


Figure 5-5: Domestic extraction of biomass by main categories, AC-13 1992-1999, in 1000 tonnes

Source: Wuppertal Institute (2002), data set C

5.3. Imports of raw materials, semi-manufactures, and final goods

Imports into the Accession Countries have significantly increased from around 250 million tonnes (1.5 t/cap) in the early 1990ies to more than 300 million tonnes (1.9 t/cap) in the late 1990ies (Figure 5-6). By this, the share of imports to the DMI has increased as well, from around 13.5 to around 16%.

Imports are dominated by fossil fuels. Biomass and other imports of semi-manufactures and final goods, attributable to neither biomass, minerals nor fossil fuels, rose most strongly. The latter indicates an increasing external economic exchange due to the opening towards international markets, i.e. international horizontal economic integration.

The increasing share of foreign DMI is also an indication of a convergence towards EU pattern.

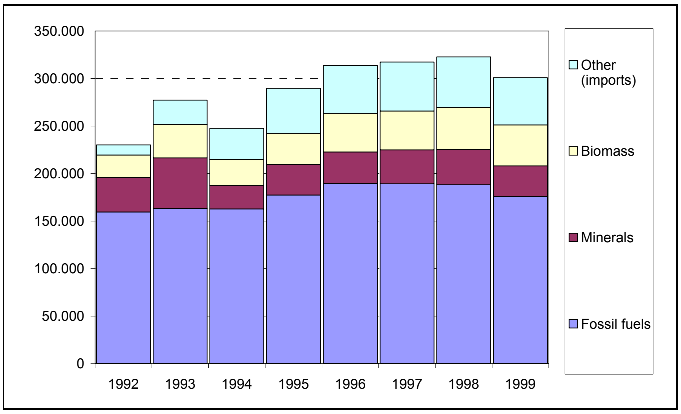


Figure 5-6: Imports by main material categories, AC-13 1992-1999, in 1000 tonnes

Source: Wuppertal Institute (2002), data set C

5.4. Benchmark comparison with average EU-15 flows

Material use in terms of DMI in the European Union is about one third higher than in the 13 Accession countries. In 2000, the DMI of the EU was 16.8 t/cap compared to 11.1 t/cap in the Accession Countries (1999) (Figure 5-7).

The difference is mainly due to a significantly lower level of domestically extracted minerals in the Accession Countries. In EU, about 8.5 t/cap of DMI are attributed to minerals. In the Accession Countries it is only about 2.8 t/cap.

With less than 2 t/cap also imports, i.e. the foreign part of DMI, are lower in the Accession countries compared to EU (3.7 t/cap). On the other hand, fossil fuel use in the Accession Countries is with 3.5 t/cap comparable to the EU use pattern with about 4.0 t/cap. The same applies for biomass: 4.3 t/cap in the EU and 4.5 t/cap in the Accession Countries.

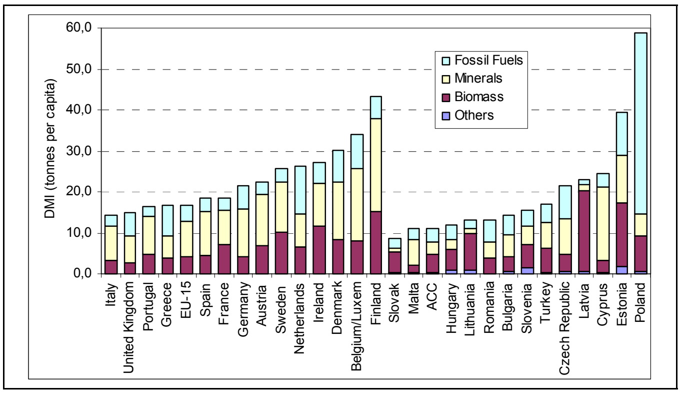


Figure 5-7: Main components of DMI by countries and country groupings, 1999

Source: EU: Eurostat & IFF (2002), data set B; Wuppertal Institute (2002), data set C

Also in the 13 Accession Countries, GDP growth has been de-coupled relatively from DMI development. Real GDP in Accession Countries increased by 33% from 1996 Euro per capita in 1992 to 2547 Euro/cap in 1999 whilst DMI increased by around 8%.

However, direct materials productivity in Accession Countries, measured as GPD per tonne DMI, is with some 230 Euro per tonne DMI significantly below the EU productivity with almost 1200 Euro per tonne DMI. In order to achieve productivity levels of the EU, Accession Countries will need to increase their resource productivity by a factor 5 or even more if one considers that the EU will increase its resource productivity in the meantime. As the following Figure 5-8shows, the growth of resource productivity in Accession Countries over the 1990ies does not look as if it will reach the EU level soon.

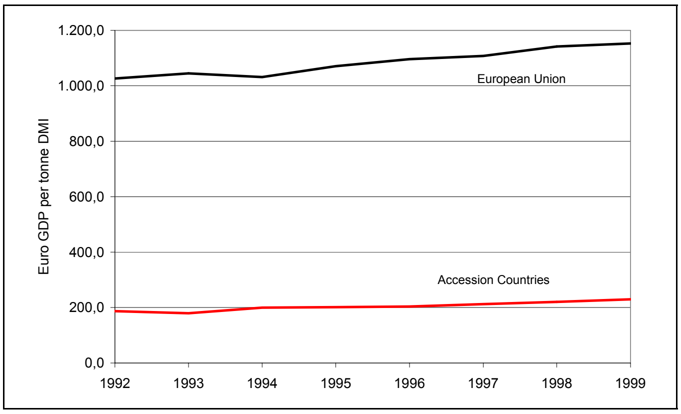


Figure 5-8: Resource productivity (GDP/DMI) 1992-1999, EU and Accession Countries, Euro per tonne

Source: EU: Eurostat & IFF (2002), data set B; Wuppertal Institute (2002), data set C

On a single country level, the relationship between GDP and DMI varies significantly across Accession Countries as can be seen from the scatterplot below (Figure 5-9).

If we compare the level of economic prosperity with the material use of the different countries, it becomes obvious that certain countries are able to generate high economic welfare from relatively low material input. Examples are Italy, UK, but also the EU as a whole. Apparently, these countries have organised their consumption and production patterns in another way than, for example, Finland which requires huge amounts of material inputs to achieve high levels of economic welfare. Finland's economy is still significantly based on natural resources. And although it has reduced domestic extraction of ores, its metals manufacturing even increased based on growing imports. In general, mining and heavy industry require a huge amount of material throughput. In contrast, economies such as Italy and the UK seem to build their economic welfare to a higher degree on less material intensive manufacturing and services. Usually, service intensive economies tend to use less direct material input. But also manufacturing sectors in countries such as Germany have increased their resource efficiency.

With regards to the Accession Countries, the question arises: Will they end up in the lower right part of Figure 5-9when they increase their GDP in future, i.e. will they be able to follow the UK and Italy model?

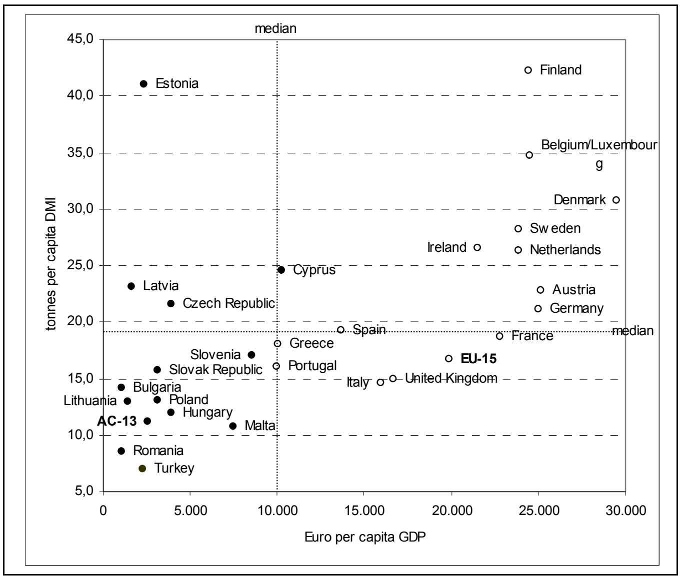


Figure 5-9: Scatterplot GDP against DMI 1999/2000, by countries and country groupings

Source: EU: Eurostat & IFF (2002), data set B; Wuppertal Institute (2002), data set C

6. Interpretation and Assessment

The following sections provide first assessments of the main resource categories (fossil fuels, metals, industrial and construction minerals, biomass) along the following criteria:

- main environmental problems associated with the particular resource category;
- dominant interfaces for interaction with environment;
- problematic resource flows;
- main use of the particular resource category (driving forces) and EU share of world production; world reserves[13];
- main options to reduce environmental implications by the respective resource category.

In the following Table 6-1an overview is given of all resource flows of the EU-15 in 1997. The single resources are ranked within their respective categories according to their contribution to the TMR of the EU. This ranking constitutes a first attempt of identifying priorities based on the information derivable from material flow accounts. It also provides how much of the particular resource is extracted domestically or imported. Furthermore, the unused ("hidden") parts and shares are given for each single resource.

[13] Reserve figures are regarded as an inappropriate measure for future availability of resources (Wellmer and Becker-Platen 2001) since they refer only to known and economically recoverable resources and are thus dependent on a number of parameters, such as exploitation techniques and innovations, type and distribution of deposits, and prices. From an environmental viewpoint it may be concluded that the grade of deposits that can be economically exploited will probably decrease which in turn will increase the specific "hidden flows" per raw material useable.

Table 6-1: Components of Total Material Requirement (TMR) of EU, 1997, with a ranking of materials according to their contribution to TMR

unit: metric tonnes	total			domestic extraction used			un-used domestic extraction			imports			hidden flows of imports		
	tonnes	t/cap	of total TMR	tonnes	t/cap	%	tonnes	t/cap	%	tonnes	t/cap	%	tonnes	t/cap	%
Fossil Fuels	5.489.462.084	14,7	28,6%	733.371.349	2,0	13,4%	2.669.141.353	7,2	48,6%	811.751.169	2,2	14,8%	1.275.198.213	3,4	23,2%
Litgnite	2.446.619.030	6,6	12,7%	244.307.000	0,7	10,0%	2.182.413.239	5,9	89,2%	2.610.985	0,0	0,1%	17.287.806	0,0	0,7%
Hard coal	1.577.226.224	4,2	8,2%	118.725.094	0,3	7,5%	450.765.104	1,2	28,6%	152.817.098	0,4	9,7%	854.918.928	2,3	54,2%
Oil	786.911.768	2,1	4,1%	155.294.000	0,4	19,7%	9.695.582	0,0	1,2%	530.901.164	1,4	67,5%	91.021.023	0,2	11,6%
Gas	366.637.355	1,0	1,9%	198.584.022	0,5	54,2%	21.721.837	0,1	5,9%	114.582.379	0,3	31,3%	31.749.117	0,1	8,7%
Electricity	279.988.014	0,8	1,5%	0	0,0	0,0%	0	0,0	0,0%	0	0,0	0,0%	279.988.014	0,8	100,0%
Other fuels	32.079.693	0,1	0,2%	16.461.233	0,0	51,3%	4.545.591	0,0	14,2%	10.839.543	0,0	33,8%	233.326	0,0	0,7%
Metals	4.359.700.452	11,7	22,7%	92.508.362	0,2	2,1%	91.048.482	0,2	2,1%	197.722.563	0,5	4,5%	3.978.421.044	10,7	91,3%
Precious metals (ores and concentrates not further specified	1.773.374.211	4,8	9,2%	0	0,0	0,0%	0	0,0	0,0%	29.553	0,000	0,0%	1.773.344.659	4,8	100,0%
Copper	772.826.275	2,1	4,0%	31.513.964	0,1	4,1%	31.091.863	0,1	4,0%	4.668.116	0,013	0,6%	705.552.332	1,9	91,3%
Iron	541.991.876	1,5	2,8%	24.366.295	0,1	4,5%	15.013.911	0,0	2,8%	151.987.372	0,408	28,0%	350.624.297	0,9	64,7%
Tin	420.118.255	1,1	2,2%	580.651	0,0	0,1%	40.020	0,0	0,0%	64.742	0,0002	0,0%	419.432.841	1,1	99,8%
Gold	370.078.608	1,0	1,9%	5.636.364	0,0	1,5%	563.636	0,0	0,2%	616	0,0	0,0%	363.877.992	1,0	98,3%
Silver	129.831.083	0,3	0,7%	12.229.335	0,0	9,4%	15.286.668	0,0	11,8%	8.403	0,0	0,0%	102.306.677	0,3	78,8%
Platinium	90.101.082	0,2	0,5%		0,0	0,0%		0,0	0,0%	218	0,0	0,0%	90.100.864	0,2	100,0%
Aluminium (Bauxite)	70.288.161	0,2	0,4%	2.040.000	0,0	2,9%	26.342.720	0,1	37,5%	15.420.841	0,041	21,9%	26.484.600	0,1	37,7%
Titanum	62.297.119	0,2	0,3%	0	0,0	0,0%	0	0,0	0,0%	1.328.724	0,004	2,1%	60.968.395	0,2	97,9%
Zinc	39.007.416	0,1	0,2%	9.207.987	0,0	23,6%	920.799	0,0	2,4%	3.075.749	0,008	7,9%	25.802.881	0,1	66,1%
Nickel	27.447.457	0,1	0,1%	2.172.078	0,0	7,9%	217.208	0,0	0,8%	569.396	0,002	2,1%	24.488.775	0,1	89,2%
Molybdenum	20.356.215	0,1	0,1%	0	0,0	0,0%	0	0,0	0,0%	90.781	0,000	0,4%	20.265.434	0,1	99,6%
Lead	13.132.929	0,0	0,1%	2.786.106	0,0	21,2%	461.722	0,0	3,5%	728.849	0,002	5,5%	9.156.252	0,0	69,7%
Industrial Minerals	554.824.868	1,5	2,9%	150.373.790	0,4	27,1%	58.843.348	0,2	10,6%	31.334.339	0,1	5,6%	314.273.391	0,8	56,6%
Diamonds a. o. precious stones	231.583.885	0,6	1,2%	0	0,0	0,0%	0	0,0	0,0%	4.988	0,0	0,0%	231.578.897	0,6	100,0%
Phosphate	69.047.723	0,2	0,4%	0	0,0	0,0%	0	0,0	0,0%	10.219.802	0,0	14,8%	58.827.921	0,2	85,2%
Industrial sands	62.538.581	0,2	0,3%	59.607.000	0,2	95,3%	738.688	0,0	1,2%	1.709.142	0,0	2,7%	483.751	0,0	0,8%
Potash	56.617.199	0,2	0,3%	14.135.300	0,0	25,0%	24.566.194	0,1	43,4%	2.107.730	0,0	3,7%	15.807.975	0,0	27,9%
Industrial clays	44.661.374	0,1	0,2%	11.379.507	0,0	25,5%	22.963.990	0,1	51,4%	5.619.651	0,0	12,6%	4.698.226	0,0	10,5%
Salt	42.687.441	0,1	0,2%	40.686.000	0,1	95,3%	455.666	0,0	1,1%	675.011	0,0	1,6%	870.764	0,0	2,0%
Peat for agriculture	8.310.354	0,0	0,0%	6.648.283	0,0	80,0%	1.662.071	0,0	20,0%	0	0,0	0,0%	0	0,0	0,0%
Abrasives	6.968.900	0,0	0,0%	6.968.900	0,0	100,0%	0	0,0	0,0%	0	0,0	0,0%	0	0,0	0,0%
Asbestos	5.325.865	0,0	0,0%	4.800.000	0,0	90,1%	480.000	0,0	9,0%	37.289	0,0	0,7%	8.576	0,0	0,2%
Magnesite	2.856.313	0,0	0,0%	1.850.000	0,0	64,8%	0	0,0	0,0%	818.141	0,0	28,6%	188.172	0,0	6,6%
Pyrite, Pyrrhotite	1.519.181	0,0	0,0%	1.428.000	0,0	94,0%	0	0,0	0,0%	53.953	0,0	3,6%	37.228	0,0	2,5%
other ind. Minerals	22.708.052	0,1	0,1%	2.870.800	0,0	12,6%	7.976.739	0,0	35,1%	10.088.632	0,0	44,4%	1.771.881	0,0	7,8%
Construction minerals	3.491.021.553	9,4	18,2%	2.822.384.380	7,6	80,8%	616.490.875	1,7	17,7%	30.945.895	0,1	0,9%	21.200.404	0,1	0,6%
Natural stone	1.423.290.249	3,8	7,4%	1.122.194.069	3,0	78,8%	251.000.747	0,7	17,6%	29.458.896	0,1	2,1%	20.636.538	0,1	1,4%
Sand and gravel	1.198.155.566	3,2	6,2%	1.044.341.468	2,8	87,2%	153.814.098	0,4	12,8%	0	0,0	0,0%	0	0,0	0,0%
Limestone, calc. Stone	759.690.221	2,0	4,0%	569.653.651	1,5	75,0%	187.985.705	0,5	24,7%	1.486.999	0,0	0,2%	563.866	0,0	0,1%
Clays	109.885.518	0,3	0,6%	86.195.192	0,2	78,4%	23.690.326	0,1	21,6%	0	0,0	0,0%	0	0,0	0,0%
Excavation and dredging	1.230.849.570	3,3	6,4%	0	0,0	0,0%	1.230.849.570	3,3	100,0%	0	0,0	0,0%	0	0,0	0,0%
Biomass	2.327.115.191	6,2	12,1%	2.170.026.061	5,8	93,2%	2.431.422	0,0	0,1%	153.615.841	0,4	6,6%	1.041.867	0,0	0,0%
Biomass from agriculture: from harvest and processing	1.301.964.243	3,5	6,8%	1.208.299.079	3,2	92,8%		0,0		93.665.164	0,3	7,2%		0,0	
Biomass from agriculture: from grazing	734.587.099	2,0	3,8%	734.587.099	2,0	100,0%		0,0			0,0			0,0	
Biomass from forestry	276.209.600	0,7	1,4%	219.488.004	0,6	79,5%		0,0		56.721.596	0,2	20,5%		0,0	
Biomass from fishing, hunting	14.354.249	0,0	0,1%	7.651.879	0,0	53,3%	2.431.422	0,0	16,9%	3.229.081	0,0	22,5%	1.041.867	0,0	0,0%
Erosion	1.645.924.009	4,4	8,6%		0,0		1.081.625.691	2,9	65,7%		0,0		564.298.319	1,5	0,0%
Other (imports)	109.892.900	0,3	0,6%		0,0			0,0		87.424.000	0,2	79,6%	22.468.900	0,1	20,4%
TMR	19.208.790.628	51,5	100,0%	5.968.663.942	16,0	31,1%	5.750.430.742	15,4	29,9%	###########	3,5	6,8%	6.176.902.138	16,6	32,2%

6.1. Fossil fuels

6.1.1. Main environmental problems associated with fossil fuels

Fossil fuels are naturally non-renewable resources. As base material used for feedstock in the chemical industry, they may end up in plastics which can partly be technically renewed (recycling).

The flows of fossil fuels which are used for combustion represent an intermedial shift of material from the earth crust into the atmosphere. As a result an outstanding environmental problem is the contribution to global warming due to the release of fossil based emissions, especially carbon dioxide. The combustion of fossil fuels also results in problematic emissions of other substances such as sulphur and nitrogen oxides which lead to a deterioration of air quality, and a dispersion of substances which leads to acidifying and eutrophication of soil and water bodies. The use of fossil fuels is also linked to severe local disturbances of landscape and natural inventories due to mining.

6.1.2. Dominant interfaces for interaction of fossil fuels with environment

The most important interface for the interaction between fossil fuels and the environment is the *outflows*-side with its fossil based emission to atmosphere. Fossil fuel born air emissions are contributing to major environmental problems, of which global warming seems to be the most threatening. An aggregated indicator comprising and weighting six greenhouse gas emissions has been developed to operationalise this problem (Global Warming Potential measured in CO_2-equivalents). CO_2, main contributor to GWP, is emitted by the combustion of fossil fuels. Other air emissions deriving from fossil fuel use are contributing to the environmental problems of acidification, ground-level ozone and eutrophication (SO_2, NO_x, NMVOC, CO).

On the *inflows*-side, the main interface is the extraction of fossil fuels with its landscape disruption, hydrological impacts, and habitat disruptions due to varying extraction volumes. In order to anticipate these effects – which are seemingly correlated with the extraction volume – it is proposed to consider the specific TMR, and specific land use per tonne fossil fuels extracted or imported.
The *stocks*-interface is not relevant for fossil fuels.

6.1.3. Problematic flows of fossil fuels

The main problematic fossil fuels are – with descending relevance – lignite, hard coal, and oil. This ranking for the EU can be derived from several indicators such as specific SO_2, specific CO_2, and specific TMR weighted by volumes.

6.1.4. Main use of fossil fuels (driving forces) and EU share on world-wide use

Fossil fuels are mainly used for energy generation by combustion technologies. Lignite and hard coal are mainly used for electricity production and partly also for industrial processing (iron and steel, petrochemicals). Beside electricity, the main uses of oil and gas are for transport and residential heating and also as feedstock for the petrochemicals industry.

EU's apparent consumption of fossil fuels in relation to world production varies across the different fuels (Table 6-2). In the case of lignite, the EU is one of the major producers and users with more than one fourth of the world production. About 3% of world-wide hard coal production takes place within the EU territory. About the same amount of hard coal is net-imported to the EU so that the actual consumption of hard coal amounts to some 7% of world production. Almost one fifth of world oil production is consumed within the EU. Only 5% of world oil production is extracted within the EU indicating that huge amounts of oil are net-imported into the EU.

Table 6-2: Fossil Fuels – world and EU production, EU apparent consumption, world reserves

	world production (1)	EU production (1)		EU apparent consumption (1)		World reserves (2)
	metric tonnes	metric tonnes	share of world	metric tonnes	share of world	metric tonnes
Fossil fuels						
Litgnite	877.476.000	237.673.000	27%	238.636.000	27%	1.197.891.000.000
Hard coal	3.663.688.000	96.299.000	3%	244.120.000	7%	1.551.335.000.000
Oil	3.194.335.000	154.856.000	5%	582.870.000	18%	146.200.500.000
Gas*	2.041.439.909	188.102.859	9%	15.279.868	16%	126.266.650.000
Electricity						
Other fuels**	22.712.000	14.601.000	64%	11.949.000	53%	145.483.000.000
(1) year 1999; source: IEA (International Energy Agency: Basic Energy Statistics of OECD Countries 2001 edition)						
(2) year 1998; source: UN: Energy Statistics Yearbook 1998						
* calculated from TJ (gross) for production and consumption; million m^3 for reserves						
** Peat						

6.1.5. Main options to reduce environmental implications of the use of fossil fuels

Due to the intrinsic characteristics and the use patterns of fossil fuels, the following general strategic approaches could be pursued in order to reduce the environmental implications of fossil fuel use:

(1) Reduction of energy demand (promoting energy savings);

(2) Increasing energy- and materials efficiency (improving energy transformation technologies);

(3) Changing energy mix towards renewables with less specific environmental implications.

6.2. Metals

6.2.1. Main environmental problems associated with metals

Metals are naturally non-renewable, but technically renewable through recycling.

The flows of metals stem from the earth crust, are used for various purposes, are released to different environmental media and are dispersed and/or accumulate in soil and sediments. Metals have different (eco-)toxic properties (e.g. heavy metals) which can affect human health and fauna and flora in the aquatic and terrestrial environment. Depending on the highly variable concentration of metals in the earth crust, the flow of primary metals is inevitably linked with various and often enormous extraction volumes of earth material which causes disturbances at various locations. Because ores are often associated with sulphides which are oxidised in the course of the mining process to form sulphurous acid which contributes to heavy metal leaching, mining fields and abandoned mines are often heavily polluted areas.

6.2.2. *Dominant interfaces for interaction of metals with environment*

The main interface for interaction between metal flows and the environment is on the *inflows*-side through the extraction of metal ores and the associated landscape disruptions, hydrological impacts, and habitat disruptions due to varying extraction volumes. Dependent on the metal ore, pollution of soil and water (heavy metals, acids) may also constitute a problem associated with the extraction technology of certain metals. Indicators proposed to anticipate these effects are the specific TMR and specific land use per tonne metal extracted or imported. Indicators on the pollution of soil and water are dependent on the metal and also regional or local circumstances.

On the *outflows*-site, polluting emission of, for example, heavy metals constitute the main interface. Information can be obtained from specifically tailored indicators such as heavy metal concentration in sewage sludge or metal content in waste from batteries.

The *stocks*-interface is an important source for the secondary supply of metals. With regards to direct environmental concerns, the stock is of minor relevance for metals.

6.2.3. *Problematic flows of metals*

Due to extraordinary high "hidden flows" (specific TMR and specific land use per tonne concentrated metal), precious metals, including gold, silver, and metals from the platinum group, are problematic metal flows. Copper is a problematic metal flow due to its high hidden flows but also due to severe pollution problems associated with the extraction technologies applied in copper mining. Tin is also perceived as a problematic metal flow due to high hidden flows and area intensive mining from alluvial deposits. Iron is a problematic flow due to its high volume of primary resource extraction. Particularly high primary energy use is associated with the extraction and further processing of copper and iron (Kippenberger 1999).

6.2.4. *Main use of metals (driving forces)*

The use of metals is manifold in industrialised economies such as the EU. In the following, industrial use patterns for the main metals are given (European Minerals Yearbook 1996-97).

Copper: More than one third of copper is used in construction (38.5%) for electrical installations, heating, refrigeration, building wire, pipes and tubes etc. The use patterns of copper in the Western World is further dominated by electrical and electronic use with again almost one third (28.7%) (telecommunications, lightning etc.). Other uses are general engineering (13.8%) (industrial equipment etc.) and transport (10%) (motor vehicles, railways, aeronautical industries). About 9% of copper is used for household appliances.

Iron: Iron is dominantly used to produce steel. Iron ore is usually fed into blast furnaces together with coke, in order to reduce the iron oxides to pig iron. Pig iron is used as a raw material for the production of steel and, to a minor extent, for iron castings in foundries or for manufacture of ferro-alloys. Steel is made either in oxygen converters, the oxygen injection allowing the elimination of the carbon contained in pig iron, or in electric furnaces, re-melting steel scrap into pure steel. Steel is mainly used in the construction sector and car manufacture.

Tin: Tin is used mainly for tinplate (30%), solder (30%), alloys (25%), and chemicals (15%). Tinplate is a thin-gauge steel sheet with a very thin tin coating electrolytically deposited on both sides, and is extensively used in the food and beverage can industries, in competition with aluminium and tin-free steel products. Tin solders are used in various combinations by electronics and electrical industries. Among the alloys, the use of bronze is to be mentioned. Bronzes are copper-base alloys containing about 10-15% tin to harden the copper. Brass, another important copper-zinc alloy, often includes tin as a component. High-grade pewter contains 90-95% tin, with copper and antimony as hardeners.

Gold: Gold is the “precious metal par excellence”. In 1995, the gold demand in the Western World countries was about 84% for jewellery, 6% for electronic uses, 3.4% for other industrial uses, 2.9% for coins, 2% for dentistry etc. The end-use pattern differs between the industrialised (Western Europe, USA, Japan) and developing countries. In the first group, jewellery account for only about 71% of the gold, with electronic uses at 13%, whereas in the second group, more than 93% of the gold is used for manufacturing jewellery. Platinum and palladium substitute for gold to some extent, but their use is influenced by price relationships and by an established consumer preference for gold. Silver can also substitute for gold, but is more subject to corrosion. Gold-plated palladium and bright tin-nickel can be used in electronics, whereas titanium and chromium-base alloys can be used in dental work.

Silver: Silver has a number of significant industrial applications. Its end-use pattern is 33% jewellery and silverware, 29% photography (commercial photography; medical, dental and industrial X ray; graphic arts), 12% electrical and electronics (connectors, contacts, batteries), 6% coinage, 20% other industrial uses (brazing alloys, mirrors, dental amalgams, catalysts, reflecting surfaces etc.). Substitutes are becoming common in several areas, e.g. stainless steel is an economic alternative in table flatware. Silver-free film and xerography have replaced silver-bearing films and together with the advent of electronic cameras this may represent a major threat to silver’s use in the future. Gold and platinum-group metals can be substituted for silver in electrical/electronic components. Aluminium and rhodium are used for reflecting surfaces mainly in high-tech appliances. In many countries silver has been replaced in coinage. Silver batteries may be replaced by lithium ones in future.

Platinum (and related metal ores): The six metals of the platinum group (PGM) are platinum, palladium, rhodium, iridium, osmium and ruthenium, with platinum and palladium being by far the most important both in weight and in overall values. The PGM are classified as precious metals, even though most of their uses are industrial. About 44% of world demand for platinum (including secondary metal) was used in the manufacture of auto catalysts, 36% for jewellery and about 4-5% each for chemicals, electrical and glass applications. For palladium, the main use was in electronics with about 42% of world demand, followed by auto catalysts (27%) and dentistry (20%). Most of the world demand for rhodium went to auto catalyst applications. Ruthenium and iridium are used in very small quantities as catalysts (ruthenium), alloys for coatings in the electrochemical sector.

Bauxite: Of all bauxite mined, about 85% is ultimately converted into aluminium metal, 10% goes to non-metalliferrous uses as various forms of alumina (Al_2O_3), and 5% to non-metallurgical grade bauxite applications such as aluminous cement, refractory and abrasive products, chemicals uses etc.
Aluminium: Aluminium is used in the packaging, building, transport, and electrical industries as well as for consumer durables, household appliances etc., with transport, building and electrical uses being the main markets for aluminium in Western Europe. The potential for aluminium substitution is often limited by relative weight (steel in machinery, appliances etc.) or cost (titanium, magnesium in the transport and structural industry). The development of new composites and alloys could reduce uses, mainly in transport applications, whilst worries over alleged health hazards could inhibit consumption for food packaging.

Titanium: Titanium minerals are mainly used in the pigment industry to produce a pure oxide (TiO2) white pigment, widely used in paints, papers and polymers. Titanium dioxide, which has no cost-effective substitute, currently accounts for more than 85% of world titanium consumption. Titanium is also used for the manufacture of welding rods, chemical compounds, fibreglass and ceramics (carbides), which accounts for about 10% of world consumption. The titanium metal industry accounts only for a few percent of the overall TiO2 consumption. About three quarters of the titanium metal output is used in commercial and military aircraft for which high strength, heat resistance and a very good weight/structural efficiency ratio are required. Non-aerospace uses are those requiring high resistance to corrosion, such as desalination and geothermal plants.

Zinc: In the Western World galvanising is by far the most important end-use of zinc (about 46% of total zinc consumption), followed by brass alloys (21%), die-casting alloys (14%), chemicals (8%), rolled zinc (6%) etc. Galvanised steel sheets and plates are mainly used in car manufacture and the building industry. Die-casting and brass alloys are used for manufacturing car engine parts, electrical household appliances etc. Various substitutes exist for zinc, such as ceramic and plastic coatings, electroplated cadmium and aluminium in some galvanising applications, and aluminium, magnesium and plastics for die-casting. Although the zinc end-use pattern is rather stable, a decrease in the use of rolled zinc (traditional roofing in countries like France and Belgium) has occurred. Variations in zinc demand are mainly related to economic cycle. Zinc consumption increases are expected in Asia, CEEC, and developing countries, where car and building industries are expanding. About 70-80% of the zinc (“slab zinc”) used in Western Europe is produced from zinc ore. Secondary zinc produced from reprocessed scrap represents about 20-30%.

Nickel: Nickel is one of the most important alloying elements in steel-making. Industrial uses include: stainless steel (66%), alloyed steels (5%), superalloys (11%), the biggest user being the aerospace industry, and various small sectors such as foundry (4%), plating (8%), Ni-based batteries etc. Stainless steel and other Ni-bearing alloys are widely recycled. Secondary nickel accounted for 49% of the stainless-steel raw materials supply in 1994 and 1995 in the Western World. Stainless-steel production is expected to remain the major end-user; commercial jet transport demands for superalloys are also expected to increase. Ni-based batteries are still a minor end-use of nickel, but this sector is enjoying 10% annual growth.

Lead: About 69% of the lead consumed in the Western World in 1994 was for the manufacture of car batteries. Other main areas of lead consumption are the chemical industries (12%), sheet and extrusions (6%), cable (3%), gasoline additives (1%) etc. Significant lead consumption increases are expected in Asia, CEEC, and developing countries, where automobile production and ownership is expanding. In western industrialised countries, environmental concerns have already limited the use of lead in end-uses such as tetraethyl and paint.

6.2.5. EU share on world-wide metal use

Although the production and use patterns vary considerably across the various metals, and for some metals statistics are incomplete (Table 6-3), there seems to be a tendency for metals to be mainly imported into the EU. Hence, the EU is less involved in production rather than further processing of metallic raw materials.

Table 6-3: Metals – world and EU production, EU apparent consumption, world reserves

	world production (1)	EU production (1)		EU apparent consumption (2)		World reserves (3)
	metric tonnes	metric tonnes	share of world	metric tonnes	share of world	metric tonnes
Metals:						
Precious metals (ores and concentrates not further specified)						
Copper*	13.200.000	0	0,0%	1.127.000	11,2%	340.000.000
Iron	1.139.000.000	22.953.265	2,0%	152.163.000	14,9%	140.000.000.000
Tin*	247.000	1.246	0,5%	-6.300	-3,4%	9.600.000
Gold*	2.540	14	0,5%	no reliable statistics		48.000
Silver*	18.081	463	2,6%	816	5,8%	280.000
Platinium*	440	0	0,0%	no reliable statistics		71.000
Aluminium (Bauxite)	139.000.000	2.185.000	1,6%	11.572.000	10,6%	25.000.000.000
Alumina	52.000.000	4.786.995	9,2%	n.a.		n.a.
Titanum**	4.800.000	0	0,0%	1.402.400	23,5%	390.000.000
Zinc*	8.700.000	676.649	7,8%	3.221.000	46,1%	190.000.000
Nickel*	1.192.000	24.000	2,0%	111.400	10,9%	49.000.000
Molybdenum*	137.000	0	0,0%	n.a.		5.500.000
Lead*	3.000.000	232.205	7,7%	472.000	17,7%	64.000.000

(1) year 2000; source: BGS (British Geological Survey: World Mineral Statistics 1996-2000)
(2) year 1995; source: European Minerals Yearbook 1996-97
(3) year 2000; source USGS (United States Geological Survey: Minerals Commodity Sheets)
* metal content

The domestic production within the EU varies across the different metals. Considerable shares of world production held by the EU are only for zinc and lead. For the same metals, the share of EU apparent consumption is also high. In the case of zinc, the EU consumes about one third of the world production (construction industry, car manufacturing). The share of EU apparent consumption is also high for titanium, iron, copper, and bauxite with more than 10% of world production.

6.2.6. Main options to reduce environmental implications of the use of metals

Due to the intrinsic characteristics and the use patterns of metals, the following general strategic approaches could be pursued in order to reduce the environmental implications of metal use:

(1) Reduction of (primary) materials demand
    Service (function) orientation
    Dematerialised product design
    Product management which extends producers' responsibility

(2) Optimising production processes with regard to life-cycle-wide primary resource requirements, including
    new technologies re-use,
    remanufacturing, and recycling

(3) Substitution by renewables as far as sensible with regard to life-cycle-wide primary resource requirements

6.3. Industrial minerals

6.3.1. Main environmental problems associated with industrial minerals

Industrial minerals are naturally non-renewable, but technically through recycling. The flows of industrial minerals stem from the earth crust, are used for various purposes such as precious assets (diamonds, precious stones) as well as for dissipative use in agriculture (mineral fertiliser), and thus are finally either deposited on land or are dispersed via soil into water bodies where they may contribute to eutrophication. Therefore the material flow related environmental performance may vary considerably. One main problem is clearly the disproportionate use of mineral fertiliser in agriculture.

6.3.2. Dominant interfaces for interaction of industrial minerals with environment

The *inflows* constitute the main interface for interaction leading to environmental problems such as landscape disruption, hydrological impacts, and habitat disruptions due to varying extraction volumes. Indicators proposed to anticipate these effects are the specific TMR and specific land use per tonne industrial mineral extracted or imported.

On the *outflows*-side, a main interface is the dissipative use and subsequent pollution (eutrophication) by the overuse of mineral fertilizer. Information can be obtained from several indicators developed to represent the eutrophication issue.

The *stocks*-interface is of minor relevance for environmental concerns. It is rather important as a monetary value asset (jewellery).

6.3.3. Problematic flows of industrial minerals

The main problematic flows of industrial minerals are precious stones (diamonds, rubies etc.) due to their enormous hidden flows, and mineral fertiliser due to the overload of agricultural fields.

6.3.4. Main use of industrial minerals (driving forces) and EU share on world-wide use

Diamonds and precious stones are mainly used for jewellery but also for several industrial applications. Industrial sands are mainly used for glass manufacture.

Phosphate and potash are mainly used in the agriculture sector. The fertiliser industry represents 90% of the phosphate market. If we include the use of phosphates in animal feed, the agriculture sector accounts for about 95% of world-wide demand. The remaining 5% are used for industrial phosphorous compounds such as detergents. Over 90% of the market for potash (a generic term covering several types of potassium salts and expressed in K_2O equivalent) is in the agricultural sector where potash is the principal and indispensable source of potassium additives. It is used for making up fertilisers either directly in the form of chloride (KCl) or mixed with other products to make up compound fertilisers. Potash is also used in industry for glassware, ceramics, batteries, drilling muds, and as a base for soaps and detergents, and in pharmaceuticals and fine chemicals.

Sodium chloride, or simply salt, is a familiar product used in both human and animal food. It has a multitude of different uses, though in quantity it is the feedstock and chemicals industries that are the largest consumers. It is used by the latter for chloride and caustic soda manufacture, the two derivatives that are employed extensively in the chemicals industry, and for plastics manufacture (PVC). Whilst chemical applications are major factors in the demand for salt, huge quantities are required for road de-icing during winters in the northern hemisphere.

The EU production and consumption patterns in relation to the world production vary across the different industrial minerals. Potash and salt are industrial minerals where domestic production and EU apparent consumption are almost equal, accounting both for about one fifth of the world markets. EU's apparent consumption of magnesite is also very high with about one fifth of world production volumes, of which 10% is produced domestically within the EU. Asbestos and phosphate is mainly imported, the EU share to world production is about 5%.

Table 6-4: Industrial minerals – world and EU production, EU apparent consumption, world reserves

	world production (1)	EU production (1)		EU apparent consumption (2)		World reserves (3)
	metric tonnes	metric tonnes	share of world	metric tonnes	share of world	metric tonnes
Industrial Minerals:						
Diamonds a. o. precious stones#	112.100.000	0	0,0%	n.a.		580.000.000
Phosphate##	141.000.000	751.291	0,5%	9.042.000	6,6%	12.000.000.000
Industrial sands	n.a.	n.a.		n.a.		n.a.
Potash+	26.400.000	4.851.316	18,4%	5.111.000	20,7%	8.400.000.000
Industrial clays	n.a.	n.a.		n.a.		n.a.
Salt	212.300.000	39.052.032	18,4%	34.200.577	18,1%	large
Peat for agriculture	n.a.	n.a.		n.a.		5.200.000.000
Abrasives	n.a.	n.a.		n.a.		n.a.
Asbestos	2.200.000	0	0,0%	131.505	5,4%	large
Magnesite	19.100.000	1.838.832	9,6%	2.593.408	20,4%	n.a.
Pyrite, Pyrrhotite++	8.600.000	454.564	5,3%	n.a.		n.a.
other ind. Minerals	n.a.	n.a.		n.a.		n.a.

(1) year 2000; source: BGS (British Geological Survey: World Mineral Statistics 1996-2000)
(2) year 1995; source: European Minerals Yearbook 1996-97
(3) year 2000; source USGS (United States Geological Survey: Minerals Commodity Sheets)
** TiO_2 content
# carats
phosphate rocks
+ K_2O equivalents
++ sulphur content

6.3.5. Main options to reduce environmental implications of the use of industrial minerals

Due to the intrinsic characteristics and the use patterns of industrial minerals, the following general strategic approaches could be pursued in order to reduce the environmental implications of the use of industrial minerals:

(1) Reduction of (primary) materials demand
- reduction of demand for precious stones

(2) Optimising production processes and substitution by renewables (e.g. biowaste for mineral fertiliser; biopolymers for semiconductors) as far as sensible with regard to life-cycle-wide primary resource requirements, including
    - e.g. reduction of disproportionate use of mineral fertiliser;
    - e.g. wide application of organic farming

6.4. Construction minerals

6.4.1. Main environmental problems associated with construction minerals

Construction minerals are naturally non-renewable, but technically through recycling.

Construction minerals stem from the earth crust and will finally be deposited again in the earth crust, although at different locations. The interference with the environment occurs at the extraction and deposition site, but more predominantly in the use phase of the materials, because in the form of additional buildings and infrastructure they cover a significantly larger area. Construction minerals mainly contribute to the net addition to stock of the physical economy thereby contributing to the increase of built-up area.

6.4.2. Dominant interfaces for interaction of construction minerals with environment

The physical *stocks* constitute the main interface for the environmental implications of construction minerals. The expansion of the technosphere and the sealing of natural and productive land are the most problematic consequences of the use of construction minerals. To indicate these effects, it is recommended to measure the land use for settlements and infrastructure and relate those to the use of construction minerals.

On the *inflows*-side, main interface is the extraction of construction minerals with the associated environmental effects such as landscape disruption, hydrological impacts, and habitat disruptions due to varying extraction volumes. Indicators to represent these effects are specific TMR and land use per unit construction mineral extracted.

On the *outflows*-side, main interface is the disposal of construction and demolition waste with similar environmental effects as on the inflows-side.

6.4.3. Problematic flows of construction minerals

The main problematic flows of construction minerals are sand, gravel, and stones due to the high overall extraction volumes and the resulting net additions to stock.

6.4.4. Main use of construction minerals (driving forces) and EU share on world-wide use

Construction minerals are used for the construction and maintenance of buildings (about 40%) and infrastructures (about 60%). The main driving forces are the quantity and quality of demand for housing and the public demand for transport infrastructures.

With the exception of some exotic natural stones (30 million tonnes), construction minerals are seldom imported but domestically extracted.

On EU average, the gross value added of the construction sector account for about 5.4% of the total GDP.

6.4.5. Main options to reduce environmental implications of the use of construction minerals

Due to the intrinsic characteristics and the use patterns of construction minerals, the following general strategic approaches could be pursued in order to reduce the environmental implications of the use of construction minerals:

(1) Reduction of (primary) materials demand
  Diminishing the amount of additional infrastructures/buildings
  Provision of (new) housing and mobility functions through improved use of existing
  infrastructures/buildings
  Extension of life-span of buildings

(2) Optimising production processes with regard to life-cycle-wide primary resource requirements, including
  New construction technologies
  Reuse, refurbishment and modernisation, and recycling

(3) Substitution by renewables (e.g. wood, fibres) as far as sensible with regard to life-cycle-wide primary resource requirements

6.5. Biomass

6.5.1. Main environmental problems associated with biomass

Biomass is naturally renewable; however, the actual regeneration depends on proper, i.e. sustainable, cultivation schemes.

The flows of biomass are produced by natural processes and originate from plants which use solar energy to synthesise a variety of organic substances. Biomass is either cultivated in agriculture, forestry and aquaculture or it stems from wild harvest (including fisheries). After use, organic residuals and their nutrient components are either recycled (only in cultivation mode) or they directly and finally enter land deposits or water bodies. The main environmental problems due to biomass use are the overexploitation of wild forests and fish reserves, and the depletion of fertile soils and the overload of manure and fertiliser through cultivation practices which are not adjusted to local environmental capacities.

6.5.2. Dominant interfaces for interaction of biomass with environment

On the *inflows*-side, the main interface is the cultivation and harvest of biomass with the associated environmental effects of landscape change through intensive wild harvest/logging and reduction/loss of soil fertility in cultivated fields. Indicators to operationalise these effects are the specific TMR (erosion) and the specific land use per unit biomass harvested.

On the *outflows*-site, the main interface is the means of cultivation which are associated with environmental problems such as the overload of nitrogen and phosphorous due to excessive application of manure and fertiliser. Indicators to illustrate these effects are nutrient balances, water quality of rivers and the North and Baltic Sea.

The *stocks*-interface is constituted by the use of biomass as a construction material. However the contribution is (still) modest and in general not relevant with regards to environmental implications.

6.5.3. Problematic biomass flows

Problematic biomass flows are in principle those stemming from unsustainable cultivation practices, such as timber from tropical and arctic forests.

6.5.4. Main use of biomass (driving forces) and EU share on world-wide use

Biomass from agriculture is mainly used for animal fodder (approximately almost 60%). Further processing to food and beverages accounts for about one third of the total biomass produced in agriculture. The remaining parts are used for industrial purposes, e.g. bio-fibre, bio-fuel etc., and seeds.

Biomass from forestry is mainly used for the manufacture of wood products, furniture etc. A rather small amount is used for the manufacture of pulp, paper and paper products and some biomass from forestry is also used as fuel.

Biomass from fisheries is mainly used for food production.

On EU average, the gross value added of the agriculture, forestry and fishing sector accounts for 2.6% of total GDP.

6.5.5. Main options to reduce environmental implications of the use of biomass

Due to the intrinsic characteristics and the use patterns of biomass, the following general strategic approach could be pursued in order to reduce the environmental implications of the use of biomass:

Optimising production processes with regard to life-cycle-wide primary resource requirements, which includes

- abandoning the use of forest products which do not stem from adequately qualified cultivation;
- fostering the wide application and further development of organic farming practices;
- stopping the use of fishery products from catches beyond sustainable yield.

6.5.6. Sustaining the supply: non-renewables versus renewables

From an ecological viewpoint, the criterion of renewability is an important one. Non-renewable resource use is related to irreversible changes of the environment. It is not the scarcity of a particular non-renewable resource which constitutes the main environmental problem. Rather, the implications of the use of non-renewables are associated with a diverse bundle of environmental problems (see also above): e.g. it is not the depletion of fossil fuel reservoirs which constitutes the main problem but the transformation and shifting from fossil carbon to the atmosphere. Other non-renewables are associated with bundles of other impacts contributing to continuous irreversible deterioration of the state of the environment.

So far we have considered the negative impacts of resource use. However, if we know what we do not want (or where we want to get), we will not automatically get what we need (or arrive where we want to be). Therefore, the discussion on the best way towards sustainable resource use will have to answer the question how to guarantee an environmentally sound supply with materials and energy. In general, a continuous supply in the future is only possible on the basis of renewable energy *and* material sources.

It is very clear that the current cultivation schemes of agriculture, forestry and fisheries are not sustainable and must be further developed towards this end. However, biomass supply from natural processes, using solar energy via photosynthesis for the production of food, feed, fibres and other renewable base materials, will be t h e future physical basis of the economy. Current biomass production still depends on a large amount of non-renewable throughput (mineral fertiliser which ends up in water bodies). In future, resource efficiency of biomass production will have to rise significantly, thus contributing to a further reduction of the demand for non-renewables and diminished losses to the environment. There will also be a certain use of non-renewable base materials (e.g. metals); however, in the future primary extraction (e.g. of ores) will only substitute for the minimised losses of the recycling routes of the economy. Currently, we are also relatively far away from a recycling economy designed to reduce the disposal of valuable residuals.

The task is to manage a complex system of resource flows based on limited knowledge. Therefore the existing generic and specific environmental pressures should be steered towards a level when critical state indicators no longer signal a continued reduction of environmental quality. The amount of non-regenerated resource use is a generic indicator which indicates the risk of detrimental impacts associated with resource extraction, subsequent use and final disposal. It is plausible that *ceteris paribus* an increase will let these risks grow, and a reduction will also contribute to reduce these risks. Even if there is no clear-cut cause-effect relationship between specific resource extractions and environmental effects such as loss of species diversity, depletion of fertile soil, reduced water quality, changed landscape, dehydration or flooding etc., the amount of resources extracted from nature which are not regenerated should be reduced – together with other substance specific measures to control the known cause-effect relationships – until the state of the environment no longer deteriorates.

7. Conclusions and Recommendations

An overview was provided on the main resource and waste flows of the EU economy, and on resource efficiency in Member States and Accession Countries. Based on a systematic and comprehensive accounting framework, the study provides information on the volume and structure of the material throughput and physical growth, i.e. the metabolism, of the EU economy and also detailed information on the main resource and waste flows as well as materials used.

The main findings show that

- direct material use and total material requirements have been decoupling from economic growth in relative terms; this implies that the market forces already favour resource efficient production which means that increased resource productivity is also relevant for reasons of competitiveness;

- direct materials productivity of the Accession Countries will have to rise by a factor of five to reach the current EU level;

- there is no absolute decline in the volume of EU's total resource requirements, which implies that the environmental burden related to resource use remains constantly high; in single countries an absolute decline has been related to policy influence, indicating that business as usual will not lead towards this end;

- it is scientifically not possible to assess which environmental impacts of resource use are of prior importance, nor to determine the various specific impacts of major resource flows which are or may become especially relevant in the short or long term; therefore, priority setting for policy measures will require political judgement;

- volume and composition of the resource requirements will have to change if the various environmental implications of resource use, material throughput and physical growth are to be diminished, and the supply not only of energy but also of materials is to be provided on a more renewable basis;

- there is a significant shift in resource requirements from domestic sources towards the use of imports and thus a shift in environmental burden of resource use to other regions; therefore, resource use is increasingly becoming a matter of international burden sharing;

- there is a continuously growing risk associated with the physical growth and expansion of the technosphere in the form of additional buildings and infrastructures which will affect future waste generation and the capacity for renewable supply and resource regeneration.

One may derive several recommendations with regards to the further development of the Thematic Strategy. Article 8 of the 6th EAP provides already quite clear indications for the further process. The overview of the EU's resource-use pattern (step a) should be followed by a policy review and assessment (step b), the formulation of objectives and targets (step c), and the anticipation of policy measures including the promotion of respective technologies (steps d and e).

Based on the findings and conclusions of this study, the recommendations have been grouped into three clusters following the general policy cycle:

1) Problem analysis
The problem analysis, underpinning a policy on sustainable resource use and management, has to be improved. Findings from this "zero-study" have to be further developed and detailed with regard to several aspects. In particular, criteria should be further developed which allow assessment of whether the use of resources in EU is sustainable or not.

Therefore, it is also necessary to further develop and detail the quantitative information on the resource-use pattern as obtained from the economy-wide MFA conducted in this study. This could be done by providing more detailed information on:

- the use-patterns of single resource categories, i.e. disaggregated material flow analyses for fossil fuels, metals, industrial minerals, construction minerals, and renewables (biomass); possibly, the material specific analyses should be extended to water and land use;

- the resource use and productivity of the different economic sectors.

The material and sector specific analyses could also be performed prospectively, i.e. scenarios of possibly sustainable resource-use patterns in Europe and beyond could be performed, considering the metabolism of society, i.e. inputs and outputs from and to the environment, as well as domestic and foreign resource use.

As a pre-requisite for this, the following improvements in information tools, sources and methodologies could be pursued:

- the material flow accounting methods and conventions will have to be developed further in order to allow the provision of harmonised data and indicators by Member States and Accession Countries;

- the data basis will have to be improved with regard to the transboundary effects of domestic resource use (esp. with regard to the hidden flows of imports and exports);

- the method of sectoral attribution of material flows (inputs and outputs) to economic sectors will have to be developed further by making use of economic and physical input-output tables;

- the development of tools for the prospective analyses of EU's resource-use patterns should be fostered.

2) Objectives
In parallel to the improvement of the information bases and the better understanding of the problem, the processes of formulating objectives and setting quantitative targets could be started.

Since a solely science-based target setting seems unrealistic, one could initiate a discursive process involving all stakeholders in order to anticipate also normative objectives as they are already indicated by the three "management rules" (see section 2.2). This "normative" process should, of course, be linked to the "objective" development of better information in an iterative way.

A possible means to express the complexity of a number of quantitative targets could be to define a "Target Metabolism" for the EU which would include already existing policy targets and scientific reference values which so far refer only to selected material flows or sections of resource use (e.g. organic farming area, percentage of renewable energy, maximum levels of municipal solid waste or GHG emissions).

3) Policy measures

Experiences with the relatively new policy field are few. What can be said is that most seemingly a bunch of several policy measures (policy mix) will be needed to address the complex issue. This requires a two-step approach:

1) the screening and assessment of existing policy measures in Member States and beyond; and a "mapping" of those material flows of the industrial metabolism which are already addressed by existing policies (e.g. fossil fuels through energy policies);

2) the anticipation of new policy measures complementing the existing policy measures in order to end up with a policy mix addressing the entire industrial metabolism; thereby, the further development of the different sectoral policies may be regarded to be of special importance (Cardiff Process).

The promotion of resource-efficient technologies will play a crucial role. Therefore, it is recommended to set up an inventory providing information on technologies and management options which may significantly contribute to reducing the environmental burden of resource use in the context of the total metabolism of the economy.

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Technical Annex

DMI accounting for EU-Accession countries (Dataset C)

1. General remarks:

Data of DMI presented in this study are largely based on international data sources. From current knowledge it appears that this procedure may lead to significant differences as compared with databases established by national experts from specific data sources and related information. Furthermore, some data for imports could not be acquired in a comprehensive way due to incomplete databases in international statistics, this concerned in particular some metals, minerals and other products for which additional estimates had to be performed as described later. The results presented in this study should therefore be considered as first and rough estimates of the material flows of the respective countries. It is recommended to further develop these databases by specific national studies with a particular view on domestic bulk minerals and biomass from grazing, and on imports. There are a few exceptions from the way of establishing databases from international sources which are:

- Data for the Czech Republic were taken directly from the original database provided by Milan Scasny as Excel-worksheets (Scasny and Kovanda 2001).
- DMI and TMR of Poland had been accounted for in an earlier study (Schütz et al. 2002) for 1992, 1995 and 1997. But for the sake of comparable, consistent time series of DMI for Poland 1992 to 1999 it was decided in this study to use the complete data series established instead. The variations from the original, more detailed database were 4.1% in 1992, and -0.2% in 1995 and 1997 respectively.
- Data for the domestic extraction of minerals in Estonia were provided as Excel-worksheets by Matti Viisimaa, Estonian Environment Information Centre, Tallin, based on data from the Estonian Statistical Board (http://www.stat.ee/).

Data for the domestic extraction and imports of energy carriers were prepared by Stephan Moll, Wuppertal Institute, from the database of the International Energy Agency (IEA) on CD-Rom.

Data for GDP and population were prepared by Stephan Moll, Wuppertal Institute, based on data from WORLDBANK and EUROSTAT.

All other data were collected by Helmut Schütz from international statistics, and partly supplemented by own estimates as described in the following.

DMI-accounts were prepared for the following countries:

- Bulgaria
- Cyprus
- Czech Republic
- Estonia
- Hungary
- Iceland
- Latvia
- Liechtenstein
- Lithuania
- Malta
- Norway
- Poland
- Romania

- Slovakia
- Slovenia
- Turkey

However, it turned out that data for Liechtenstein were full of gaps and consequently it was decided to omit the results in this study. DMI data for Iceland showed very high shares of the estimated amounts of grazing of livestocks on greenland, and because this represents a rather uncertain material flow position it was decided to skip the results for Iceland as well.

2. Domestic extraction

In general the accounting of the domestic extraction of direct resource inputs from the domestic environment was performed in this study as described in the EEA Technical report No.56 (Bringezu and Schütz 2001a) and in the EUROSTAT Working Paper 2/2001/B/2 (Bringezu and Schütz 2001b). Deviations from these basic accounting procedures will be pointed out in the following.

2.1. Fossil fuels

Data for the domestic extraction of energy carriers were prepared by Stephan Moll, Wuppertal Institute, from the database of the International Energy Agency (IEA) on CD-Rom.

They comprised the following materials:

- Hard coal (1000 tonnes)
- Lignite/Brown Coal/Sub-Bituminous Coal (1000 tonnes)
- Peat (1000 t)
- Natural Gas (TJ - gross)
- Crude Oil (1000 t)
- Natural Gas Liquids (1000 t)

Original units other than tonnes were converted using technical coefficients from the database of the UN Energy Statistics.

2.2. Minerals

Data for the extraction of minerals (of metallic and non-metallic kinds) were collected from two sources:

- United Nations Industrial Commodity Statistics Yearbook (UNICSY) 1998 (data from 1992 until 1998)
- United States Geological Survey (USGS) series "The mineral industry of …" available as pdf-format under http://minerals.usgs.gov/minerals/pubs/country/ (data from 1992 until 1999)

A general limitation in both sources was that some actual data are characterized as preliminary or estimates and time series thus become less reliable for most recent data. Furthermore, it turned out that USGS data for clays in Estonia were by three orders of magnitude too high (Matti Viisimaa, Estonian Environment Information Centre, Tallin, personal communication), and minerals data for the Czech Republic also differed significantly from the national database of Scasny and Kovanda (2001). There is therefore uncertainty associated with the use of non-confirmed USGS data, but it was far above the possibilities of the present study performed within about one month to use original national databases for the accounts confirmed by national experts.

In general the procedure in this study was to combine the UN and the USGS database for a seemingly rather complete account of the domestic extraction of minerals. This resulted in two major accounts, one for ores and the other for industrial minerals (a term of USGS which includes minerals for construction). The characteristics and limitations of these two accounts are characterized in the following table:

Metals:	
Bulgaria	USGS data; comments in Ores-USGS worksheet.
Cyprus	Copper ores reported only by UNICSY 1998
Hungary	Combined database USGS plus UNICSY 1998; only UN reports uranium from the Mecsek uranium mine which was closed in 1997 for financial reasons, since then U for nuclear power plants is imported. UN reports on gold production, but there is no evidence for domestic extraction of that.
Norway	USGS data; decline from 1995 to 1999 is mainly because of iron, followed by copper and titanium.
Poland	USGS data
Romania	Combined database USGS plus UNICSY 1998; decline is mainly because of iron ore.
Slovakia	USGS until 1993, Combined database USGS plus UNICSY 1998 since 1994 (for Mercury); decline is mainly because of copper, iron, gold, tin-tungsten and zinc.
Slovenia	UNICSY data from 1992 to 1994 based on USGS data reported for 1992 only.
Turkey	USGS data
Industrial minerals:	
Bulgaria	Combined database USGS plus UNICSY 1998.
Cyprus	USGS data
Hungary	USGS data
Iceland	USGS data
Latvia	Critical: Sand, silica and quartz from UNICSY mainly causes decline from 1992 to 1993, values differ much from USGS, clarification is needed !!!
Lithuania	Critical: limestone for cement from USGS mainly causes decline from 1992 to 1995, no data until 1995 from UNICSY.
Malta	USGS data
Norway	Combined database USGS plus UNICSY 1998.
Poland	Critical: Sand, gravel and stones 92 to 94 estimated based on 95 ratios of old to new time series !!!
Romania	Combined database USGS plus UNICSY 1998; decline is mainly because of gravel and crushed stone from UNICSY.
Slovakia	USGS data
Slovenia	Critical: Sand, gravel and stones 92 to 94 estimated based on 95 ratios of old to new time series !!!
Turkey	Critical: Dolomite 92 to 94 estimated based on 95 ratios of old to new time series !!! The sharp increase 1995 to 1996 is mainly because of "limestone other than for cement" from USGS, no explanation found for this.

2.3. Biomass

Domestic extraction of biomass comprised the following material groups:

- Harvested biomass in agriculture
- Ancillary biomass from harvest in agriculture
- Grazing of livestock on permanent pastures
- Roundwood production by forestry
- Fish catch

With the exception of grazing and ancillary biomass all biomass data were taken from the electronic database of the FAO (FAOSTAT, http://apps.fao.org).

Ancillary biomass from harvest was estimated based on empirical coefficients for the amounts of leaves of fodder- and sugar-beets and straw of cereals. This accounting procedure is comparable with the one proposed by EUROSTAT (2001a) for metals, i.e. including the ancillary mass within the DMI. Furthermore, there is empirical evidence from German agricultural statistics that at least part of these ancillary biomasses are used within the economy as feedstuffs for the livestock (there are also other types of use possible). For the countries studied here ancillary biomass accounted for a maximum of 4.5% of DMI (Hungary) and a minimum of 0.1% (Malta), the median for all countries being 1.2%.

The biomass input by grazing of livestock on permanent pastures was in principle estimated by the same procedure as described before (Bringezu and Schütz 2001a,b). In this study, however, assumed yields for grazing were substantially lower than those of the previous studies, partly oriented at the grazing yields derived from our material flow study for the United Kingdom (Bringezu and Schütz 2001c), partly oriented at country-specific yields for harvested green fodder plants where these data were available in FAOSTAT. In detail the grazing yields were assumed as follows (in tonnes per ha):

Country	Item	Element	1992	1993	1994	1995	1996	1997	1998	1999
Bulgaria	Green fodder plants; Median 95-99	Yield Mt/Ha	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0
Cyprus	Grazing yields UK * 0,5	Yield Mt/Ha	4,0	4,0	4,0	4,0	4,0	4,0	4,0	4,0
Estonia	Green fodder plants; Median 95-99	Yield Mt/Ha	8,3	8,3	8,3	8,3	8,3	8,3	8,3	8,3
Hungary	Green fodder plants; Median 95-99	Yield Mt/Ha	3,1	3,1	3,1	3,1	3,1	3,1	3,1	3,1
Iceland	Grazing yields UK * 0,33	Yield Mt/Ha	2,6	2,6	2,6	2,6	2,6	2,6	2,6	2,6
Latvia	Grazing yields UK	Yield Mt/Ha	8,0	8,0	8,0	8,0	8,0	8,0	8,0	8,0
Lithuania	Grazing yields UK	Yield Mt/Ha	8,0	8,0	8,0	8,0	8,0	8,0	8,0	8,0
Malta	Green fodder plants; Median 95-99	Yield Mt/Ha	8,1	8,1	8,1	8,1	8,1	8,1	8,1	8,1
Norway	Grazing yields UK * 0,5	Yield Mt/Ha	4,0	4,0	4,0	4,0	4,0	4,0	4,0	4,0
Poland	Green fodder plants; Median 95-99	Yield Mt/Ha	4,9	4,9	4,9	4,9	4,9	4,9	4,9	4,9
Romania	Grazing yields UK	Yield Mt/Ha	8,0	8,0	8,0	8,0	8,0	8,0	8,0	8,0
Slovak Republic	Grazing yields UK	Yield Mt/Ha	8,0	8,0	8,0	8,0	8,0	8,0	8,0	8,0
Slovenia	Grazing yields UK	Yield Mt/Ha	8,0	8,0	8,0	8,0	8,0	8,0	8,0	8,0
Turkey	Grazing yields UK	Yield Mt/Ha	8,0	8,0	8,0	8,0	8,0	8,0	8,0	8,0

Our initial estimate of grazing in EU-countries was based on an average yield of 14.7 tonnes grazing per hectare permanent pasture not harvested. This yield is in hay weight as it was derived from the Statistics of the German Ministry of Agriculture reporting on this basis. Similar yields are reported for grazing on Irish pastures (McGee 2000) with average annual yields of grazed grass of 11 tonnes dry matter per hectare for the northern part of Ireland and 14 tonnes dry matter per hectare for the southern part of the country. Applying an average utilization rate of 75% (McGee 2000) and a water content of 17% in hay weight (Mäenpää and Vanhala, 2002) the respective Irish hay weight yields would be about 10 and 13 tonnes per hectare and, thus, corroborate the yields we assumed for our estimates. The estimates performed here for the studied countries therefore represent most probably rather estimates at the lower end of potential values. For the countries studied here grazing accounted for a maximum of 30% of DMI (Iceland) and a minimum of 0% (Malta), the median for all countries being 7%. As described above results for Iceland were not considered in this study.

Besides the described method it was also tried in this study to estimate grazing by feedstuff requirements of the reported livestock (the latter numbers taken from FAOSTAT). In this case specific feedstuff requirements were derived from official German agricultural statistics (BMVEL) which are corroborated by empirical coefficients for individual animal types (Malik, Wuppertal Institute, unpublished). From this the total greenfeed requirements of the individual countries' total livestock was calculated in hay weights. From the resulting total greenfeed estimate the reported harvested greenfeed was subtracted to derive the potential amount of greenfeed from grazing. However, the results of this procedure were rather diverse and even leading to negative numbers in many cases, so that the current approach was not considered suitable as an alternative method for estimating grazing. In some cases the estimation by feedstuff requirements resulted even in substantially higher numbers than obtained from the estimate based on land use and grazing yields.

Certainly, the estimation of grazing by livestock needs substantial further methodological development based on international expertise and harmonization efforts.

3. Imports

There are no complete international statistics available for the foreign trade of the studied countries. Therefore data had to be gathered from a variety of sources comprising the following main parts:

- All commodities imported from (respectively exported by) the European Union: data from the EUROSTAT (2001b) COMEXT database on CD-Rom.
- All imported energy carriers from any origin (total imports): data from IEA-database on CD-Rom differentiated by raw materials and semi-manufactures.
- Imported commodities from agriculture, forestry and fishing from any origin (total imports): data from FAOSTAT (http://apps.fao.org).
- For some metals (Bauxite, Alumina, Aluminium, Copper ore, Unrefined Copper, Refined Copper, Iron ore, Lead ore, Lead metal, Manganese ore, Ferromanganese, Nickel ore, Nickel intermediate products, Nickel unwrought, Tin ore, Tin metal, Tungsten ore, Zinc ore, Zinc metal) and minerals (Phosphate rock and Sulphur) total imported quantities for 1992 and 1993 were taken from the UNCTAD Commodity Yearbook.

Therefore, the imports of any kind from the European Union, of all fossil fuels (energy carriers), of all biomass and of some minerals and metals in 1992 and 1993 can be considered as completely covered by the available statistical sources. Missing data therefore concern some minerals, metals and other products from non-EU countries.

In order to estimate these missing imports of commodities from non-EU countries the following procedure was chosen:

1. Multipliers for the Czech Republic imports were calculated by: original data from Scasny and Kovanda (2002) divided by data acquired in this study: the resulting values ranged from 1.22 in 1994 to 1.44 in 1999 with increasing tendency.
2. Multipliers for Poland's imports were calculated for 1992 (1.06), 1995 (1.44), and 1997 (1.34) by: original data from Schütz et al. (2002, derived from original foreign trade statistics of Poland) divided by data acquired in this study.
3. For 1992 the Polish multiplier was used, for 1995 and 1997 the averages of the Polish and Czech multipliers, and intermediate multipliers were derived from linear inter- and extrapolation of these values. This resulted in multipliers from 1.06 in 1992 to 1.36 in 1999 with increasing tendency.

These multipliers were used to estimate the total imports of Bulgaria, Estonia, Hungary, Latvia, Lithuania, Romania and Slovakia (i.e. countries assumed to have similar features like Poland and Czech Republic as regards foreign trade relations and their development during transition processes of the economies) from the data acquired in this study. The imports of Cyprus, Malta, Norway, Slovenia and Turkey remained as they were available in this study and are therefore underestimated to an uncertain extent. The shares of the known imports of the latter countries in DMI of 1999 are 23%, 49%, 10%, 30%, and 15% respectively, indicating the requirement for further data acquisition by specific national studies.

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