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Material use indicators for the European Union, 1980-1997

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CONTENTS

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Material use indicators for the European Union, 1980-1997

Economy-wide material flow accounts and balances and derived indicators of resource use

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Preface

Eurostat is working on **economy-wide material flow accounts and balances** as part of work to develop environmental accounts linked to national accounts. Economy-wide material flow accounts provide aggregate descriptions of the material flows through economies. Important indicators of material use and material efficiency can be derived from these accounts.

In March 2001, Eurostat published a guidebook entitled '***Economy-wide Material Flow Accounts and derived Indicators – A Methodological Guide'*** (Office for Official Publication of the European Communities, Luxembourg). This Guide provides a framework and practical recommendations for establishing material flow accounts and balances and for deriving a set of physical indicators for a whole economy. It offers harmonised terminology, concepts and a set of accounts and tables for implementation.

The Guide also offers help to compilers on the types of accounts to be implemented first, on data sources and methods and on the interpretation of the derived indicators. Compilers are encouraged to base their work on the concepts and classifications presented in the Guide.

For several Member States economy-wide material flow accounts and balances have already been compiled. A selection of these compilations has been published by Eurostat (see overleaf for a list of Eurostat environmental accounting publications and Working Papers).

This Working Paper presents the results of work undertaken by the Wuppertal Institute for the European Commission's Directorate General for the Environment and Eurostat. The Working Paper provides estimates of a set of material-related indicators for the EU-15 and per Member State. The Working paper also documents the data sources and methods used for establishing the data set from which the indicators were derived.

Key results showing the EU's Direct Material Consumption (DMC) have been included in the Eurostat publication '***Measuring Progress Towards a More Sustainable Europe - Proposed Indicators for Sustainable Development'*** that was prepared for the June 2001 Gothenburg European Summit.

The Wuppertal Institute was also involved in preparing *Economy-wide Material Flow Accounts and derived Indicators – A Methodological Guide*. The handbook and the work presented in this Working Paper were completed at the same time. Therefore, the terminology and concepts used in this Working Paper are largely but not entirely consistent with the Guide.

Eurostat distributes this Working Paper hoping that compilers of economy-wide material flows and researchers can benefit from the methods and data presented.

The work on economy-wide material flow accounts is continuing at Eurostat. The focus is on refining and regularly producing material flows data sets and indicators of resource use for EU-15 as well as advancing the interpretation of the indicators and the analytical uses of the accounts.

Brian Newson
Head of Unit B1
National accounts methodology,
statistics of own resources

Eurostat Environmental Accounting publications

Official publications

- Environmental Taxes – A Statistical Guide (2001)
- Economy-wide Material Flow Accounts and derived Indicators – A Methodological Guide (2001)
- Accounts for Subsoil Assets – Results of Pilot Studies in European Countries (2000)
- Valuation of European Forests - Results of IEEAF Test Applications (2000)
- Environmental Taxes in the EU – Statistics in Focus Theme 2 – 20/2000
- European Handbook for Integrated Environmental and Economic Accounting for Forests – IEEAF (2000)
- Pilot Studies on NAMEAs for air emissions with a comparison at European level (1999)
- The Environmental Goods & Services Industry – Manual for data collection and analysis (OECD/Eurostat, Paris 1999)
- The European Framework for Integrated Environmental and Economic Accounting for Forests: Results of pilot applications (1999)
- From research to implementation: policy–driven methods for evaluating macro-economic environmental performance – proceedings from a workshop, Luxembourg 28-29 September 1998 (DG Research Report Series 1999/1)
- The European System for the Collection of Economic Information on the Environment – SERIEE 1994 Version (1994). Also available in DE, FR and ES.

Eurostat Working Papers

- Uses of Environmental Accounts in Sweden (2/2001/B/1)
- Environment taxes and subsidies in Danish NAMEA (2/2000/B/12)
- Environment taxes and environmentally harmful subsidies in Sweden (2/2000/B/11)
- The environment industry in Sweden, 2000 (2/2000/B/10)
- Material flow analysis in the framework of environmental economic accounting in Germany (2/2000/B/9)
- A materiel flow account for Italy, 1988 (2/2000/B/8)
- Environment employment in France, methodology and results 1996-1998 (2/2000/B/7)
- Material flow accounts - material balance and indicators, Austria 1960-1997 (2/2000/B/6)
- The environment industry in Sweden, 1999 (2/2000/B/5)
- Environment industry and Employment in Portugal, 1997 (2/2000/B/4)
- Environment-related employment in Netherlands, 1997 (2/2000/B/3)
- Material flows accounts – DMI and DMC for Sweden, 1987-1997 (2/2000/B/2)
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- A material flow account for sand and gravel in Sweden (2/1999/B/4)
- The Environment Industry in Sweden (Nr. 2/1999/B/3)
- Industrial Metabolism (Nr. 2/1999/B/2)
- The Policy Relevance of Material Flow Accounts (Nr. 2/1999/B/1)
- The Economy, Energy and Air Emissions (Nr. 2/1998/B/2)
- Physical Input-Output Tables for Germany, 1990 (Nr. 2/1998/B/1)
- An Estimate of Eco-Industries in the European Union 1994 (Nr. 2/1997/B/1)

Eurostat internal publications

- Natural resource accounts and environmental Input-Output tables for Greece 1988-1998 (9/2000)
- Statistics on Environmental taxes and other economic instruments for environmental protection in EU Member States (11/1999)
- Material Flow Accounting – Experience of Statistical Institutes in Europe (12/1997)

Internet: http://europa.eu.int/eurostat.html

Contents

Objectives and summary

The **objectives of the work** were:

(1) Establishing a *framework and method description for drawing up aggregate material balances nationally*. The method description is designed for application nationally by statistical services of Member States.

(2) Providing an *estimate of an aggregate material balance for the EU based on available statistics for the period 1980-1998*. To this end, an accounting model and data system were established and documented that allow compiling an aggregate material balance for the EU by main categories of materials and by Member States. The accounting model and data system will allow easy update based on available information and will also support incorporation of material balances compiled by Member States, as these become available in more Member States.

Two major *activities* were *performed* to meet the objectives:

A) Preparation of a report with the method description for establishing material balances nationally

B) Estimation of an aggregate material balance for the EU 1980-1998

A methodological report was prepared in collaboration with Eurostat and the Eurostat Task Force on Material Flow Accounting. Based on this work, Eurostat published „*Economy-wide Material Flow Accounts and Balances with derived Indicators – A Methodological Guide*“ in 2001 (see chapter 2).

The data system, the accounting, its results and remaining problems with potential solutions for deriving economy-wide material flow accounts, balances and indicators for the EU are described in great detail in the present report (especially chapters 3 to 9 and Annex „Accounting model and data system“). Establishing the aggregate material balance comprised the model design for the EU with a description of data available and the compilation of time series.

In the course of the work several data problems arose. According to the availability of data on unused extraction, outputs to the environment and stock increases, the work plan was adjusted together with Eurostat to assure that valid indicators were provided. Where missing data turned out to constitute a major problem for some of the derived indicators, recommendations were given for improving the data situation in the future.

This report builds upon the first study on Total Material Requirement (TMR) of the European Union (EU-15) 1995 to 1997 performed by the Wuppertal Institute for the EEA[1]. The present study went several steps further, (1) by establishing TMR time series from 1980 to 1997, (2) by accounting for Domestic Material Consumption (DMC) and the Physical Trade Balances (PTB), (3) by establishing, for the first time, time series from 1990 to 1996 of material outputs to the environment from the EU economy which allowed to derive (4) Net Additions to Stock (NAS), and (5) comprehensive Material Balances for EU-15 from 1990 to 1996.

From 1980 to 1997 the European Union underwent a significant development with the accession of Greece in 1981, Portugal and Spain in 1986, the former East Germany in 1990, and Austria, Finland and Sweden in 1995. During this period the EU-15 *population* had increased by 5% and its *GDP* by 42%. *Total Material Requirement* (TMR including erosion) of EU-15 from 1980 to 1997 varied between plus 9% and minus 4% of the level of 1980 (FIGURE 1). The order of

[1] Bringezu and Schütz 2001a,b.

magnitude remained rather constant. Thus, *economic growth in EU-15 was relatively decoupled from TMR*. However, relatively constant absolute TMR levels indicate a continuing pressure to the environment due to total material resource requirements of the EU economy.

From 1980 to 1997 the EU had reduced its dependence on *domestic total resource extraction* in absolute terms. In 1997 the share of domestic extraction was 61% of TMR and the level of domestic extraction was 17% lower than in 1980, mainly due to reduced fossil fuels extraction. However, during this period environmental pressure had increasingly been shifted to other countries due to *imported commodities and associated hidden flows*. In 1997 the level of foreign hidden flows was 29% higher than in 1980. Most of these requirements for foreign resources are due to EU-15 demand for minerals and metals, in particular for luxury and precious commodities.

In an *international comparison* the 50 tonnes per capita TMR of the EU-15 were significantly lower than in the US (88 t/cap in 1994), and slightly higher than in Japan (42 t/cap in 1994). Within the EU, TMR per capita varied considerably between Member States. For instance, Finland, Germany and the Netherlands required 84 t/cap, 73 t/cap and 68 t/cap, respectively, whereas the UK performed with 38 t/capita. TMR per capita of Poland is still significantly lower than the EU-level (around 30 t/cap) and must be expected to rise in the course of future accession.

In 1997, 95% of the direct material inputs to the EU economy were domestically consumed. The *Direct Material Input (DMI)* and the *Domestic Material Consumption (DMC)* of the EU-15 grew only by 8% and 6%, respectively, from 1980 to 1997, and since 1989 the level has been rather constant (FIGURE 1). *This led to a relative decoupling of GDP from DMI and DMC*. From 1980 to 1997 direct material productivity of EU-15 had increased by 31%, domestic material consumption productivity by 33%. In per capita terms, only Germany (minus 3%) and France (minus 7%) had decreased their dependence on direct material inputs. Per capita domestic material consumption had been reduced in the UK (minus 2%), the Netherlands (minus 5%), Germany (minus 7%), Sweden (minus 8%), France (minus 11%) and Finland (minus 14%).

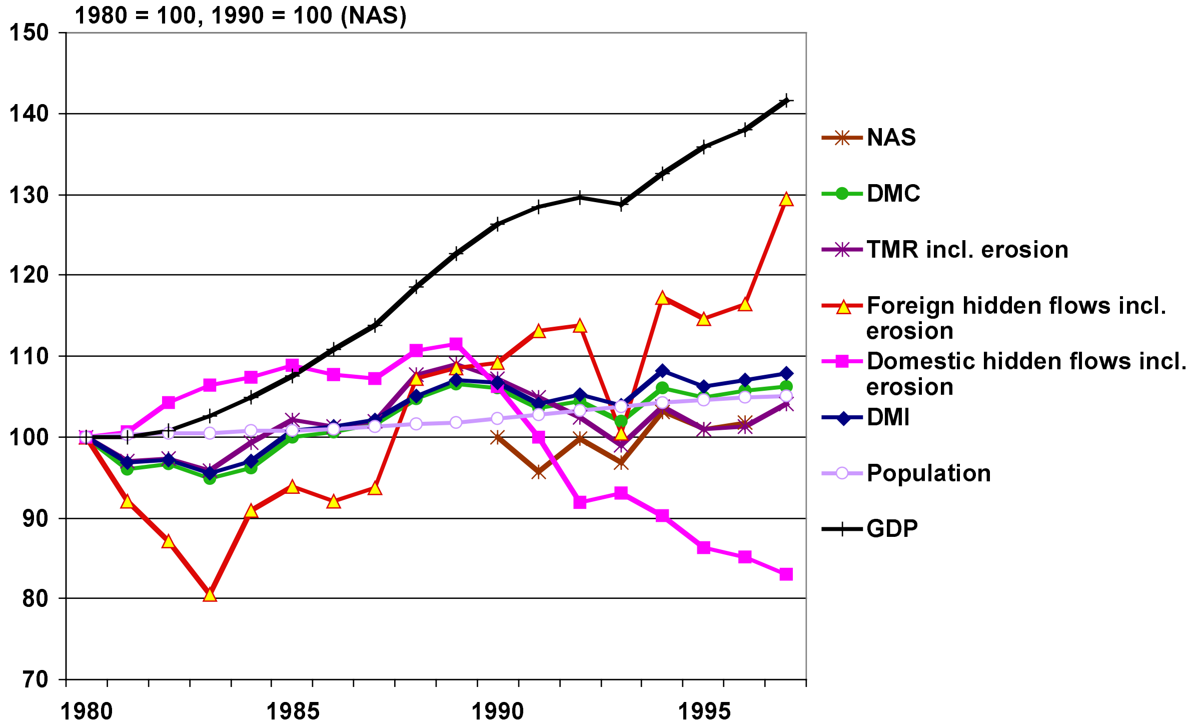
From 1980 to 1997 the EU was a net importer of commodities (shown as a positive *Physical Trade Balance – PTB*), mainly due to fossil fuels imports which end up as material outputs of the EU economy to the environment within the same year. Among the 15 Member States only the UK, Greece and Sweden sporadically exported a higher mass of commodities than they imported. In general, however, the EU and its Member States are using more foreign resources than they are providing to other economies.

From 1990 to 1996 *total domestic outputs to the environment (TDO)* from the EU-15 economy declined slightly by 13% (in absolute terms). This was due to the reduction of domestic hidden flows, mainly unused extraction of fossil fuels. *Domestic processed outputs (DPO)* remained constant during that period and their share in TDO rose from 38% to 43%. Carbon dioxide was the dominant contributor to DPO in the EU with a proportion around 80%. No reduction of *CO_2 emissions* took place in the EU in the study period. Business as usual will lead to a continuation of current trends. Thus effective action is required to fulfil the targets of the Kyoto Protocol and further reductions envisaged in the 6th Environment Action Programme. Significant absolute reductions of material outflows in EU-15 were recorded for *SO_2 emissions* from 1980 to 1997. However, not all Member States had decreased sulphur dioxide emissions. Significant increases were recorded for Greece and Portugal.

The EU-15 and its Member States, as well as Japan and USA, are characterised by continuing *Net Additions to Stock (NAS)*. Therefore, these industrial economies are growing steadily in physical terms at the expense of naturally productive land. This situation is far from sustainable.

Comprehensive *Material Balances of EU-15* were derived for 1990 to 1996. Certainly, they need further refinement especially as more detailed studies on economy-wide material flow accounts of the Member States become available. The material balances developed during this study may serve as a first comprehensive basis for reviewing priorities for policy based on the knowledge of the whole system, and to further develop the use of material flow indicators in regular statistics. Future research and societal processes may develop a vision of a sustainable economy, and a target material flow balance may be one of the next building blocks towards this end.

Figure 1: Population, GDP, main material flow indicators and aggregates: EU-15 1980-1997, indexed.



1. Introduction

1.1. The policy context

As stated in the conclusions of the Heads of State meeting of the European Union countries in Helsinki in December 1999 (European Council 1999), a net reduction in the use of natural resources will be needed to bring economic growth in line with the Earth´s carrying capacity. To this end economic performance and requirements for natural resources must be decoupled. In other words, resource efficiency should be increased. As outlined by the EEA before (European Environment Agency 1999a,b), this strategy is regarded as a prerequisite for an absolute delinking of economic growth and resource consumption. In Helsinki in July 1999, the environmental ministers of the EU agreed that targets and timetables should be set, where appropriate, for improving eco-efficiency in the different sectors and the development monitored with appropriate indicators[2].

As a proposal for target development, the factor 4 to 10 concept has often been mentioned (see European Environment Agency 1999b, Gardener and Sampat 1998) since its formulation by

[2] http://presidency.finland.fi/netcomm/eventcal/showarticle.asp?intNWSAID=2370&intIGID=6&tapah_id=84).

Schmidt-Bleek (1993) and Weizsäcker et al. (1995). In order to reduce global resource extraction by half, industrial countries should increase the efficiency of overall primary resource requirements of energy and materials in the next 30 to 50 years by four to ten times. The factor 4 to 10 goal had been noted by the OECD environmental ministers in 1996 and was adopted by the UNGASS in 1997. In some of the EU Member States it stimulated political debate, e.g. in Germany, the Netherlands and Sweden, and became part of political programmes, e.g. in Austria and Finland, and subject to specific research (see especially Nordic Council of Ministers: „Factors 4 and 10 in the Nordic Countries"). Within the context of integrated environmental and economic accounting, some EU Member States such as Austria, Denmark, Germany, Finland, Italy, Sweden, and the UK have started to monitor the use of natural resources more comprehensively and to relate this to economic performance and industrial sectors (see e.g. DETR 1998, 1999a,b, 2001; Ministry of the Environment of Finland and Eurostat 1999).

In a first international comparison the Total Material Requirement (TMR) and the resource productivity were analysed for Germany, Japan, the Netherlands and the USA (Adriaanse et al. 1997). This „Resource Flows Report" found wide international resonance.

For measuring changes in consumption and production patterns, the UN presented a core set of indicators where the Total Material Requirement (TMR) represented a major driving force (United Nations 1998). In order to help operationalise the eco-efficiency concept, the EEA (1999b) proposed a set of EU environmental 'headline' indicators. Under the issue of 'Resource Use' the 'ideal' environmental headline indicator of „Total Material Requirement (TMR)" was chosen. The EEA commissioned a study by the Wuppertal Institute providing first estimates and methodology descriptions for the accounting of TMR of EU-15 (EEA technical reports No. 55 and 56 – Bringezu and Schütz 2001a,b).

In 2000, Eurostat established a methodological guide for MFA and derived indicators (see Eurostat 2001). It comprises overall material flow balances and aggregated indicators on total resource requirements, resource efficiency and total domestic outflows to the environment. The guide which had drawn from experience of the Wuppertal Institute and national statistical offices of EU Member States provided the basic frame for the present study. Work on the prestne study and on the Guide proceeded in parallel. This study and the Guide were completed at the time. Therefore, the terminology and concepts used in this study are largely but not necessarily fully consistent with the Guide.

In 2001, the European Commission presented its Sixth Environment Action Programme of the European Community 2001 – 2010 entitled „Environment 2010: Our Future, Our Choice"[3]. It identifies four areas where new efforts and impetus are needed. The Commission proposes to take strong action to:

- Tackle climate change
- Protect nature and wildlife
- Address environment and health issues
- Preserve natural resources and managing waste

[3] http://www.europa.eu.int/comm/dgs/environment/index_en.htm.

The main objectives within these four priority areas for action are:

- Tackle climate change: to stabilise concentrations of greenhouse gases in the atmosphere at a level that will not cause unnatural variations in the Earth's climate[4].
- Protect nature and wildlife: (1) protect and where necessary restore the structure and functioning of natural systems; (2) halt the loss of bio-diversity both in the European Union and on a global scale; (3) protect soils against erosion and pollution.
- Address environment and health issues: : achieve a quality of environment where the levels of man-made contaminants do not give rise to significant impacts on, or risks to, human health.
- Preserve natural resources and managing waste: (1) to ensure the consumption of renewable and non-renewable resources does not exceed the carrying capacity of the environment. (2) to achieve a de-coupling of resource use from economic growth through significantly improved resource efficiency, dematerialisation of the economy and waste prevention[5].

To ensure that actions taken will lead to success, progress should be measured through indicators and benchmarking. This is the starting point of the present study which will demonstrate that economy-wide material flow accounting provides a set of indicators for measuring progress towards achieving many of the objectives within the priority areas for action of the 6th Environment Action Programme of the European Commission.

It is the material metabolism of the economy which relates to greenhouse gas emissions and climate change. Resource extraction and agriculture contribute to soil degradation. The physical growth of the technosphere leads to the expansion of built-up area and a loss of productive and natural land. Thus, adequate knowledge on the metabolic performance of the EU economy will not only allow to preserve natural resources and improve the managing of waste. It will be a pre-requisite for solving problems of priority concern.

1.2. Economy-wide material flow accounting

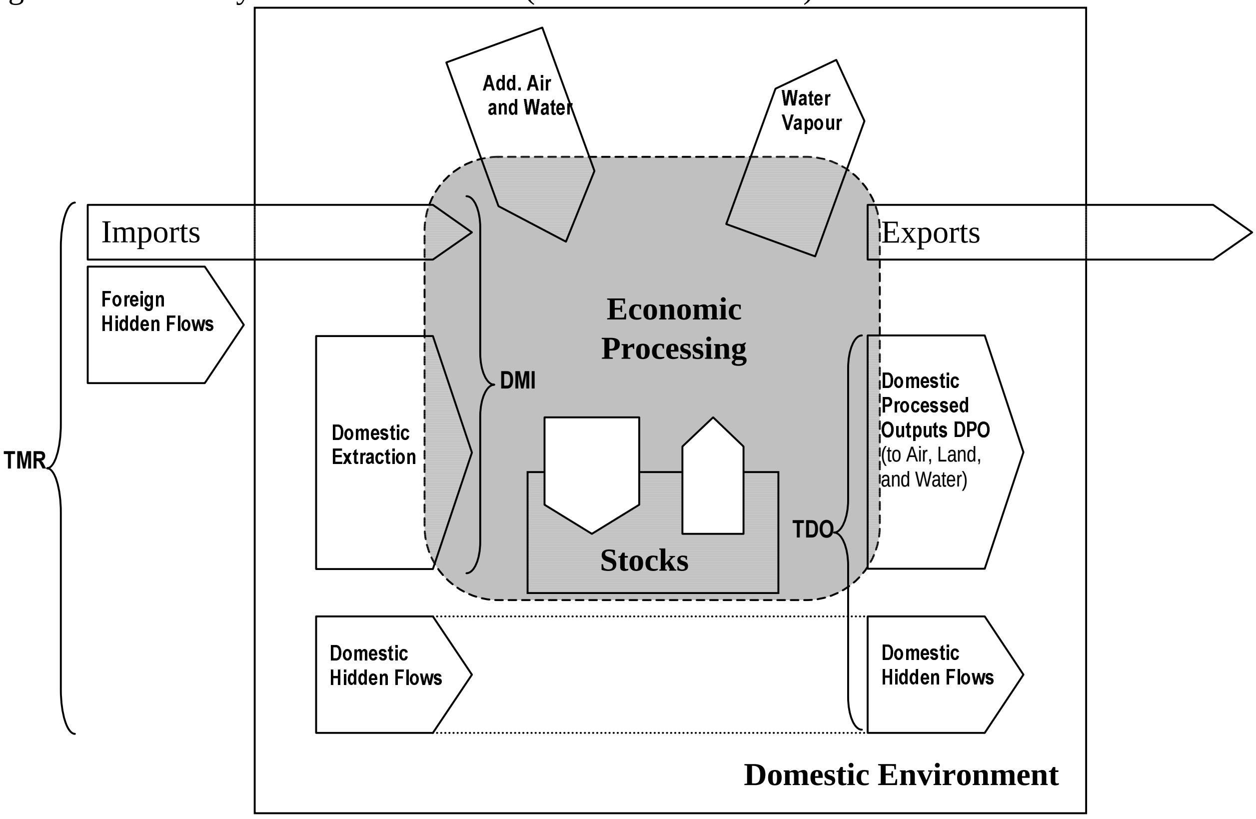
Material flow accounts (MFA) may quantify the physical exchange of national economies with the environment. Aggregated material flow balances comprise domestic resource extraction and imports (inputs) and domestic releases to the environment and exports (outputs) (FIGURE 1.1). Upstream or downstream flows associated with imports and exports (resource requirements or emissions) may also be accounted. A sectoral disaggregation can be provided by physical input-output tables.

Economy-wide MFA was applied by official statistics within the framework of integrated environmental and economic accounting (SEEA) and a methodological guide has been published by Eurostat (2001) in the course of work for the present project. National material flow accounts exist for Austria, Denmark, Germany, Finland, Italy, Japan, the Netherlands, Sweden, United Kingdom and USA. Work is ongoing for China, Egypt, and Amazonia.

[4] In the short to medium term emissions are aimed to be reduced as agreed at Kyoto (by 8% compared with 1990 levels by 2008-12). In the longer term emissions should be reduced even by 40% compared with 1990 levels by 2020. The long-term goal of a 70% reduction in emissions set by the IPCC is adopted for the first time.

[5] Waste prevention is to prioritise, followed by recycling, waste recovery and incineration, and finally, only as a last resort, land filling. Targets are to reduce waste to final disposal by 20% on 2000 levels by 2010 and by 50% by 2050.

Figure 1.1: Economy-wide material flows (Matthews et al. 2000).



The system boundary of materials flow studies is the interface between the natural environment and the economy. Materials cross the boundary between environment and economy when they are extracted. Materials recross the boundary back into the environment when they are no longer used in the economy. So far "hidden Flows" (HF) had been used synonymously with Rucksack Flows (RF) or simply rucksacks. They comprise non-used extraction of domestic input and up-stream resource requirements of imports (or exports or any product). In the Eurostat Methodological Guide, the terms "Unused domestic extraction" and "Indirect Flows associated to imports (exports)" have been introduced, with a further differentiation of indirect flows into the "Raw material equivalent of imports (exports)" and "Unused extraction associated to imports (exports)" (see Eurostat 2001). Because final agreement on these concepts was only reached by December 2000, the present study could not implement these new concepts. In this study, the terms "domestic hidden flows" (which is a synonym for unused domestic extraction) and "foreign hidden flows" (a synonym for indirect flows associated to imports) are often used.

All countries obtain physical inputs from their domestic environments, and from other countries, via imports of commodities, semi-manufactures, and finished goods. These inputs are transformed via technical and economic process chains into the following: materials that accumulate in the economy as net additions to stock in the form of long-lived durable goods and infrastructure; outputs to the environment in the form of wastes, emissions, discharges, system losses, and dissipative flows; and exports to other countries**.** Outputs to the environment occur at every stage of the process chain, from extraction to final disposal. In some cases, an output is avoided by recapturing wastes, which are returned to an earlier step in the chain, for example, through recycling. In other cases, the economic system chooses to release materials to the environment as controlled wastes. In still other cases, the nature of the losses and uses of a material preclude recapture (system losses, dissipative flows).

1.3. Material flow account based indicators

Material flow accounts provide an important basis for the derivation of environmental indicators and indicators for sustainability (Berkhout 1999, Jimenez-Beltran 1998, Ministry of the Environment of Finland and Eurostat 1999). In order to monitor and assess the environmental performance of national and regional economies a variety of indicator systems has been proposed (Moldan et al. 1997). As a framework the Driving Force-Pressure-State-Impact-Response[6] (DPSIR) scheme has been established (EEA 1999, 1999a, OECD 1998a). The extraction of resources on the input side and the release of emissions and waste on the output side of an economy relate to environmental pressures, (sectoral) activities represent driving forces, the flows may change the state of environment which give rise to various impacts and the societal or political response may influence the metabolic situation towards sustainability.

MFA based indicators have been introduced to official reports to provide an overview on the headline issues of resource use, waste disposal and emissions to air and water as well as eco-efficiency (EEA 2000, DETR 1999, Hoffren 1999, Eurostat 2001).

On the one hand, economy-wide material flow accounts provide a more comprehensive picture of the industrial metabolism than single indicators. On the other hand, they can be used to derive several parameters which - when taken in time series and for international comparison - provide aggregated information on the metabolic performance of national or regional economies (Figure 1.1 and Table 1.1). First international comparisons have been provided by Adriaanse et al. (1997) and by Matthews et al. (2000). Other examples have been reviewed in Bringezu (2000c). Recently, material flow based indicators have been derived for the United Kingdom (Bringezu and Schütz 2001c).

Table 1.1: Material flow indicators and aggregates: an overview.

Indicator classes	Indicators or aggregates		Accounting rules	Links of accounting identities
	Acronym	Full name	(##)	(#)
Input				
	DMI	**Direct Material Input**	**DMI = Domestic raw materials + Imports**	**DMI = DPO + NAS + Exports = DMO + NAS**
	TMR	**Total Material Requirement**	**TMR = DMI + HF (or IF)**	
	TMI	Total Material Input	TMI = DMI + hidden flows domestic	TMI = TMO + NAS
	HF or IF aggregates	Hidden flows or Indirect material flows	HF=IF = hidden flows domestic + hidden or indirect material flows imported	
Output (#)				
	DPO	**Domestic Processed Output**	**DPO = emissions + waste**	
	TDO	**Total Domestic Output**	**TDO = DPO + hidden flows domestic**	
Consumption				
	DMC	**Domestic Material Consumption**	**DMC = DMI - Exports**	
	TMC	**Total Material Consumption**	**TMC = TMR - Exports - hidden or indirect material flows exported**	
Balance				
	NAS	**Net Additions to Stock**	**NAS = DMI - DPO - Exports**	**NAS = DMC – DPO**
	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	
Consistency to be developed				

(#): Further aggregates on the Output side are:

DMO	Direct Material Output	DMO = DPO + Exports
TMO	Total Material Output	TMO = TDO + Exports

(##): in addition to the accounting rules shown, balancing items have to be included.
These balancing items are:
on the material input side: oxygen (O2) for the combustion of fuels and for the respiration of humans and livestocks.
on the material output side: water vapor from the combustion of fuels and water vapor,
and CO2 from the respiration of humans and livestocks.

Input indicators

Direct Material Input (DMI) measures the input of used materials into the economy, i.e. all materials which are of economic value and are used in production and consumption activities; DMI equals domestic (used) extraction plus imports.

[6] since the early nineties as PSR used especially by OECD.

Materials that are extracted by economic activities but that do not normally serve as input for production or consumption activities (mining overburden, etc.) are called "unused extraction". In earlier work they have been included in the concept of 'hidden flows' or 'ecological rucksacks'[7]. Unused extraction is not used for further processing and usually without economic value. DMI plus unused *domestic* extraction equals *Total (domestic) Material Input (TMI).*

Total Material Requirement (TMR)[8] includes, in addition to TMI, the upstream hidden material flows which are associated with imports and predominantly burden the environment in other countries. It measures the total 'material base' of an economy, i.e. the total primary resource requirements of an economy. Adding these upstream flows converts imports into their 'primary resource extraction equivalent' (including unused extraction).

Data for TMR and DMI (incl. its structure) have been provided for China, Germany, Netherlands, Japan, USA, Poland, Finland and the European Union. DMI is also available for Sweden and Austria. Work is ongoing for Italy and Amazonia. TMI was compiled for Australia.

Output indicators

Domestic Processed Output (DPO) represents the total mass of materials which have been *used in the domestic economy*, before flowing into the environment. These flows occur at the processing, manufacturing, use, and final disposal stages of the economic production-consumption chain. Exported materials are excluded because their wastes occur in other countries. Included in DPO are emissions to air, industrial and household wastes deposited in landfills, material loads in wastewater, materials dispersed into the environment as a result of product use (dissipative flows), and emissions from incineration plants. Material flows recycled in industry are not included in DPO.

Direct Material Output (DMO): The sum of DPO and exports. This parameter represents the total quantity of direct material outputs leaving the economy after use either towards the environment or towards the rest of the world.

Total Domestic Output (TDO): The sum of DPO and disposal of unused domestic extraction. This indicator represents the total quantity of material outputs to the environment released on the domestic territory by economic activity.

Total Material Output (TMO) also includes exports and therefore measures the total of material that leaves the economy; TMO equals TDO plus exports.

Consumption indicators

Domestic material consumption (DMC) measures the total amount of material directly used in an economy, excluding hidden flows. DMC equals DMI minus exports.

Total material consumption (TMC) measures the total primary material requirement associated with domestic production and consumption activities. TMC equals TMR minus exports and their hidden flows.

Net Additions to Stock (NAS) measures the physical growth rate of an economy. New materials are added to the economy's stock each year (gross additions) in buildings and other infrastructure, and materials incorporated into new durable goods such as cars, industrial machinery, and household appliances, while old materials are removed from stock as buildings are demolished, and durable goods disposed of.

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[7] Hidden flows (Adriaanse et al. 1997) or rucksack flows (Schmidt-Bleek et al. 1998, Bringezu et al. 1996) comprise the primary resource requirement not entering the product itself; hidden flows of primary production = unused domestic extraction; hidden flows of imports = unused and used predominantly foreign extraction associated with the production and delivery of the imports.

[8] in studies before Adriaanse et al. (1997), TMR had been defined as TMI (Total Material Input) (Bringezu 1997)

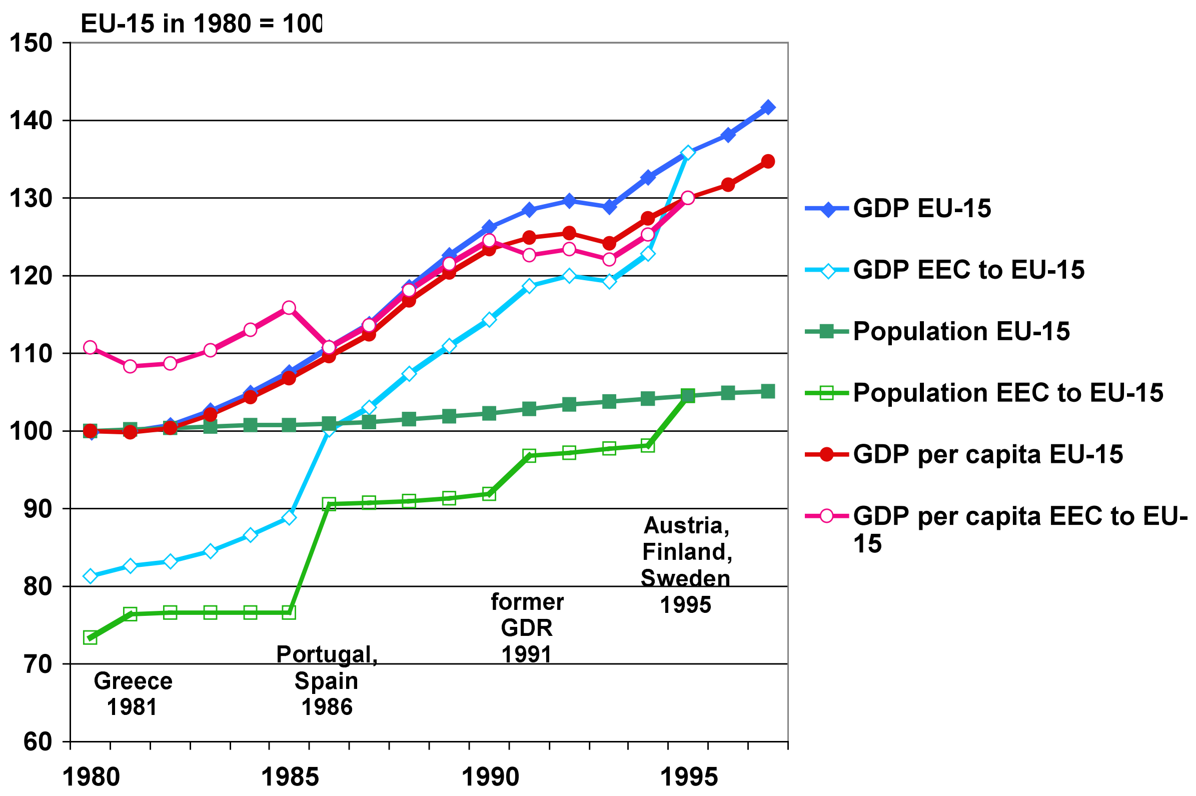
Physical Trade Balance (PTB) – measures the physical trade surplus or deficit of an economy. PTB equals imports minus exports. Physical trade balances may also be defined including hidden flows associated with imports and exports (e.g. on the basis of TMC accounts).

Efficiency indicators
Services provided or economic performance (in terms of value added or GDP) may be related to input, consumption or output indicators to provide efficiency measures. For instance, GDP per DMI indicates a direct material input productivitiy. GDP per TDO measures the economic performance in relation to material losses to the environment. Setting value added in relation to the most important inputs and outputs provides information on the eco-efficiency of an economy. The interpretation of these measures should also consider the trends of the absolute parameters. The latter are usually also provided on a per capita basis to support international comparison.

1.4. Material flow data availability for the EU

One task of the project was to provide an estimate of an aggregate material balance for the EU based on available statistics for the period 1980-1998[9]. However, during that time the EU membership underwent significant changes. In 1981 Greece joined the European Community, in 1986 Portugal and Spain. In 1990 the former GDR was reunited with the Federal Republic of Germany[10], thus increasing the EU territory. The latest expansion of the European Union EU-15 resulted from the accession of Austria, Finland and Sweden in 1995 (FIGURE 1.2). Twelve candidate countries are negotiating for accession.

Figure 1.2: Development of the EU population, GDP and GDP per capita for EU-15 territory 1980-1997, as compared to the actual EEC data 1980-1994, indexed to EU-15 in 1980 = 100.



[9] This work builds upon a first database, developed by the Wuppertal Institute for the EEA, Copenhagen, to account for TMR of the EU-15 (Bringezu and Schütz 2001a,b).
[10] German re-unification took place on 3 Oct. 1990. Official statistics for re-united Germany are mostly from 1991.

The gradual development of the European Union is associated with inconsistent statistics being available. A consistent time series of major material input flows and indicators for EU-15 based on statistical data could be established for 1995 to 1997. For 1980 to 1994 several estimates had to be performed to derive EU-15 data from the available EEC time series (see Annex).

Concerning material outputs to the environment available data gaps were much wider than for inputs. Without estimation procedures (also described in the Annex) it would not have been possible to derive any of the major indicators DPO, TDO or NAS, respectively the EU material balance, for even one single year. Nevertheless, based on these estimates a comprehensive material balance for EU-15 could be derived for 1990 to 1996.

2. The methodological guide

A method description for compiling aggregate material balances nationally was jointly developed with Eurostat and the Eurostat Task Force on Material Flow Accounting at its two meetings in 2000. This resulted in the publication of „Economy-wide material flow accounts and balances with derived indicators – a methodological guide " (Eurostat 2001). The document describes a general framework for establishing material flow accounts and balances for a whole economy. It gives basic definitions and classifications for material inputs and outputs. Indicators derived from the material balance, accounting rules for material inputs and outputs as well as related data sources and methods are described. Furthermore, the guide contains a system of accounts for national material flow balances and proposed tables for a first implementation. In the annexes of the methodological guide, details on several issues are presented.

The Eurostat Guide represents the state of the art of economy-wide MFA. It was commonly agreed by the Task Force members and is designed to support countries in setting up of material flow accounts and regularly provide key indicators for sustainability.

Since the first economy-wide material balances for Austria, Germany and Japan a community of researchers and statisticians has developed the method and tested the use of MFA. In 1996 the network ConAccount was established to provide a platform for information exchange on MFA (www.conaccount.net). A first inventory on MFA projects and activities was provided (Bringezu et al. 1998a). Several meetings took place (Bringezu et al. 1997a, 1998b, Kleijn et al. 1999) and a research and development agenda was defined (Bringezu et al. 1998c). The publication in 1997 of 'Resource Flows: the material basis of industrial economies'[11] contributed as catalyser. In the follow-up study (Matthews et al. 2000) international comparability was achieved for material output flows from the economies of USA, Japan, Austria, the Netherlands and Germany.

The Eurostat Methodological Guide sets out to support and further advance this standardisation process. Main objectives were to achieve:

- a common core set of definitions, classifications and terminology for economy-wide material flow accounts and material balances
- a common set of staged accounts which together represent the full balance but allow flexible compilation of those parts of the balance considered most relevant nationally
- a common pool of basic standards and conventions on units of measurement and coverage of individual accounts (i.e. inclusion of certain material flows)

[11] by World Resources Institute, Wuppertal Institute, Netherlands Ministry of Housing, Spatial Planning, and Environment and the Japanese National Institute for Environmental Studies.

The Guide also offers help to accountants in terms of:
- recommendations on the types of accounts to be implemented first
- likely data sources and methods
- standard tools including tables for the conversion of units of measurement and (default) coefficients for indirect material flows (synonyms: hidden flows, ecological rucksacks, upstream flows)
- recommendations for likely undercoverage to be investigated, and methods to estimate missing data
- an understanding of how the structure and development trends of an ‘average’ industrialised country look like and the factors that are likely to influence the structure and trends (e.g. the size of a country’s economy influences the importance of foreign trade flows, industrial structure and density of population may have an impact, etc.).

With respect to further development of the methodological guide and its application the Eurostat Task Force on Material Flow Accounting concluded that priorities for future work should be:
- Coefficients of a generic nature should be collected. The scientific background for these parameters (e.g. chemistry) and other meta-data should also be collected. The database should include e.g. the stochiometric equations for combustion and the associated transformations into weight; transformation from units such as m^3 to kg (density); effective thermal value (MJ/m^3 –> MJ/kg) etc.
- A database with coefficients for indirect flows should be implemented and maintained.
- Wider application of the principles outlined in the Guide should be encouraged and the experience pooled and analysed.
- Implementation exercises on the Austrian approach (aggregated PIOT) to test this intermediate/interface level accounting.
- The Guide should be complemented by a more technical compilation handbook once more experience is available and coefficients are collected.
- The Task Force should continue working on the meaning, interpretation, use and policy relevance of the indicators.
- Work on stock accounting should be expanded.

3. Total Material Requirement

Total Material Requirement (TMR) measures the total ‘material base’ of an economy, i.e. the total primary resource requirements of the economy.

The first international study on the Total Material Requirement (TMR) of USA, Japan, the Netherlands and Germany (Adriaanse et al. 1997) had set a certain standard for material flows to be included in the accounting. This standard had been largely adopted by subsequent TMR studies in other countries including a study for the European Union (EU-15) prepared for the EEA (Bringezu and Schütz 2001a,b). This standard was also largely accepted in the Methodological Guide (Eurostat 2001). However, in the Eurostat guide soil erosion from agricultural land was taken out of the main material flows contributing to TMR and classified as an optional ‘memorandum item‘.

In the present study soil erosion is included in the TMR indicator but shown as a separate item wherever possible. This was done for three major reasons:
- First, protecting soils against erosion and pollution is one major objective of the priority area for action „protecting nature and wildlife“ of the 6th framework programme of the European

Commission (see also chapter 1.1). It is further connected to the priority area „sustainable use of natural resources and management of wastes". The programme says that especially renewable resources like soil are under severe pressure from human society. No doubt, soil erosion is causing severe pressure to soil due to human activity.

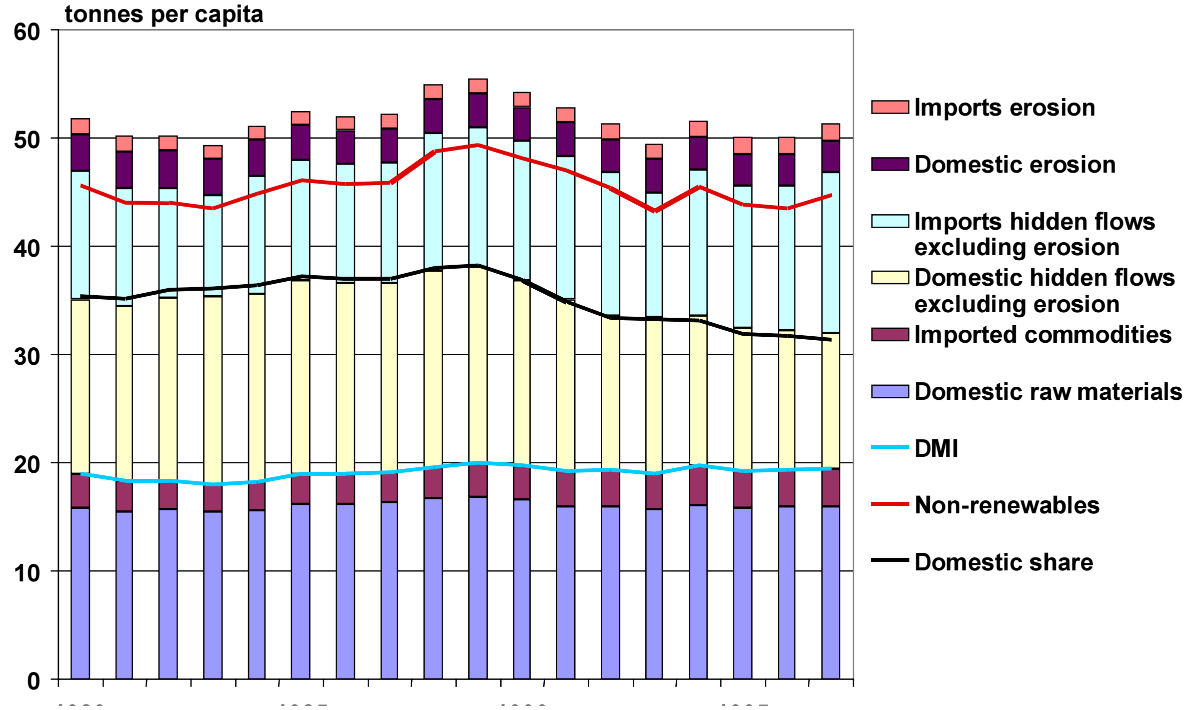
- Second, whereas in some Member States of the EU, like in the UK, soil erosion seems to be no major obstacle to sustainable development, it represents a serious threat in other countries especially of Southern and Eastern Europe. The 6th Environment Action Programme states in this context: „...in parts of the south, soil erosion is beginning to create deserts. We must take action to preserve these irreplaceable natural resources before it is too late. ... Until now, soil protection has not been a major policy for the European Union, but given the extent of the pressure from pollution and from erosion, a new policy must be developed".
- Third, for international comparisons soil erosion data should be available. Especially in the U.S. the importance of this environmental information is out of question which has led to the development of an adequate official reporting system by the government. In addition, in some cases soil erosion cannot be subtracted from international aggregated data, a circumstance that makes international comparisons of resource flow indicators excluding relevant amounts of erosion obsolete.

As in most other international TMR studies done so far, any hidden or indirect flows of imported (and exported) finished products were left out from the accounting of material flow indicators. Some of them were, however, estimated based on available coefficients and included in the database. This is described in the Annex.

3.1. TMR of the European Union

From 1980 to 1997 TMR of EU-15 fluctuated slightly around the level of 50 tonnes per capita (FIGURE 3.1)[12]. The order of magnitude remained rather constant.

Figure 3.1: TMR per capita by main aggregates, EU-15, 1980-1997.



[12] TMR of EU-15 had for the first time been estimated for 1995 to 1997 in a study of the Wuppertal Institute for the EEA (Bringezu and Schütz 2001a,b).

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. 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 and remained with slight variations at a level around 18.6 to 19.2 billion tonnes or 50 to 52 tonnes per capita until 1997.

The share of non-renewable materials (or better: non-regrowing materials, i.e. materials other than biomass) in TMR ranged from 43 to 49 tonnes per capita. Higher levels of these flows contributed most to the maximum of TMR during the middle of the study period. From 1980 to 1997 non-renewables accounted for 87% to 89% of TMR.

Domestic extraction accounted in total for 61% to 73% of TMR (31 t/cap to 38 t/cap). Higher shares were recorded during the first part of the study period. The contribution of domestic supply decreased since 1986 to the lowest proportion of 61% in 1997.

The used part of TMR is indicated by DMI. DMI ranged between 36% and 39% of TMR in the period 1980 to 1997. The domestic DMI (15.5 to 16.9 tonnes per capita) and foreign DMI (2.5 to 3.6 tonnes per capita) were fairly constant throughout the study period.

The per capita domestic hidden flows excluding erosion (i.e. the unused domestic extraction) showed variations between 12.5 to 18.2 tonnes per capita with its highest level in 1989. This was mainly due to unused extraction associated with fossil fuels which had been reduced to 67% of the level of 1980 until 1997, whereas the unused extraction associated with minerals and with excavated soil for constructions had remained more or less at the same level from 1980 to 1997.

Hidden (i.e. indirect) flows associated with imports excluding erosion varied between 9.4 and 15 tonnes per capita from 1980 to 1997 with the highest value being reported for 1997. This was mainly because of imported precious metals as raw materials and semi-manufactured products (e.g. silver, gold and platinum-group metals as ores, concentrates or ingots).

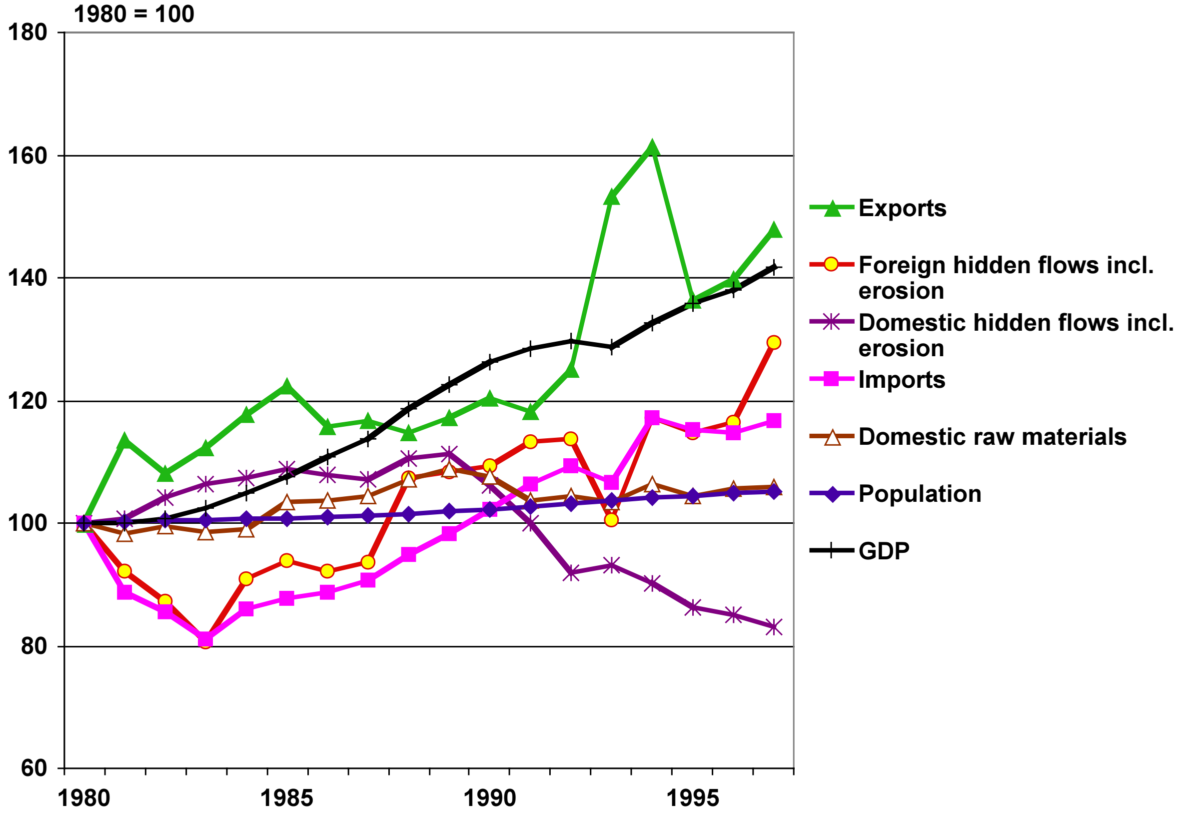
Domestic and foreign soil erosion was between 1.6 and 1.7 billion tonnes from 1980 to 1999 or about 4.4 and 4.9 tonnes per capita (which represents between 8 and 9.6% of TMR).

In comparison with socio-economic data for population and GDP, the relative developments of domestic raw material‘ extraction, imports, domestic and foreign hidden flows (HF) and exports are shown in FIGURE 3.2. EU-15 population grew by about 5% from 1980 to 1997. From 1980 to 1997 there was less variation in the domestic material extraction than for imports and especially for exports. There was a significant peak of exports in 1993 and 1994 which followed some kind of plateau between 1985 and 1992.

The most obvious changes occurred with hidden flows. The domestic part of hidden flows increased by 11% from 1980 to 1989. After 1989 domestic hidden flows declined constantly to a level of about 83% of 1980. In contrast, hidden flows attributed to imports increased during the second half of the study period and in 1997 were about 29% above the level of 1980.

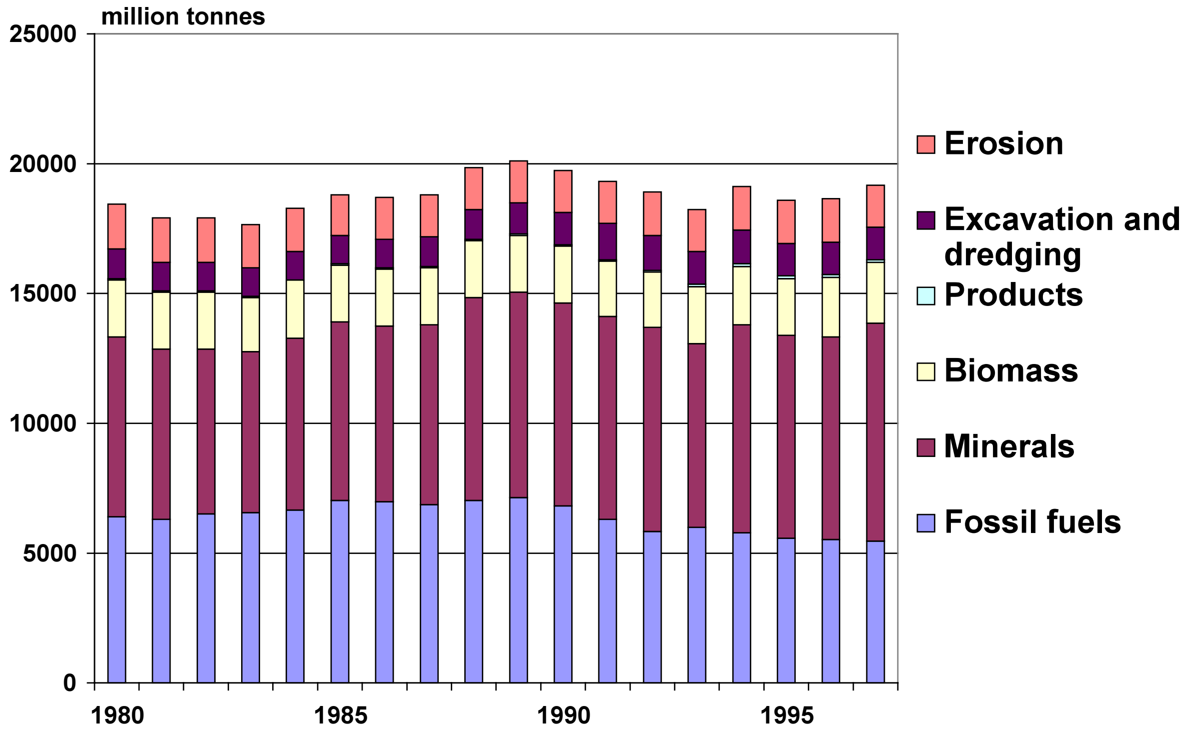
The data show that the increase of GDP, which rose by about 42% during the study period, was coupled with the increase of material flows of imports and foreign hidden flows since 1983. Development of exports indicate a particularly close coupling to GDP, with physical imports having risen much faster than physical imports. TMR and domestic resource requirements had decoupled from GDP and remained constant. The temporal trends of the material productivities per unit gross domestic product will be described later (see chapter 5).

Figure 3.2: Population, GDP, commodities flows and hidden flows: EU-15 1980-1997, indexed.



A closer look at the main material groups constituting TMR of the EU reveals that minerals and fossil fuels are the dominant material requirements. Actually, mineral resource requirements exceed the extraction of fossil fuel resources (FIGURE 3.3). Fossil fuels show a declining trend from 37% to 29% from 1980 to 1997 whereas minerals follow an increasing trend from 35% to 44% from 1980 to 1997. Biomass (11% to 12%) and erosion (8% to 10%) contribute similar shares to TMR. Interestingly, the use of green biomass in EU-15 (from different parts of the world) is associated with nearly the same amount of agricultural soil mass lost by erosion (in different parts of the world). Here, forestry harvest is included but erosion in forests is neglected. Thus, per unit of an average agricultural product the relation is even more unfavourable. In comparison, domestic excavation (total soil and earth excavation for construction) and dredging has a share between 6% and 7% of TMR.

Figure 3.3: Main material groups of TMR EU-15 1980-1997.



3.2. International comparison of TMR

FIGURE 3.4 shows the TMR in per capita terms for the EU from 1980 to 1997 in an international comparison. As it was impossible to derive consistent time series for TMR excluding soil erosion for most data of the other countries this comparison was made for TMR including soil erosion[13]. In the early phase of the period studied, per capita TMR varied considerably, with USA at about 100 tonnes per capita, Finland, Germany and Netherlands each at about 60 tonnes per capita, UK and Japan at about 40 tonnes per capita. TMR per capita for the EU-15 was measured from 1980 on at about 50 tonnes per capita throughout the period. TMR of Poland was only available for 1992, 1995 and 1997 at 28 to 32 tonnes per capita with increasing tendency.

Over time the per capita trends of USA, Finland, Germany and Netherlands converge at about 80 tonnes per capita in the early 1990s. After 1993, however, TMR per capita of Finland continued to increase to almost 100 tonnes per capita in 1999. The decline in U.S. TMR per capita in the early years of the period was due primarily to major reductions in soil erosion after the enactment of the Conservation Reserve Programme, which paid farmers not to farm highly erodible lands, and the completion of much of the federal interstate highway system. The sharp rise in German TMR 1991 reflects the reunification with the former East Germany (from 1975 to 1990 data for Western Germany only). Until 1988 TMR per capita of the UK was almost the same as for Japan. After 1988, TMR per capita of Japan increased slightly to a level of about 45 tonnes per capita until 1994. The TMR per capita of the UK increased to about 40 to 43 tonnes per capita during the 1990s[14].

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[13] Only for the UK (0.8 tonnes per capita in 1994) and Japan (0.7 tonnes per capita) it is not significant whether soil erosion is included or not. For other countries soil erosion contributes significantly more to TMR per capita: 2.6 tonnes in Finland, 4.7 tonnes in EU-15, 8 tonnes in Germany, 12.9 tonnes in USA and 19.5 tonnes in the Netherlands (in 1993).

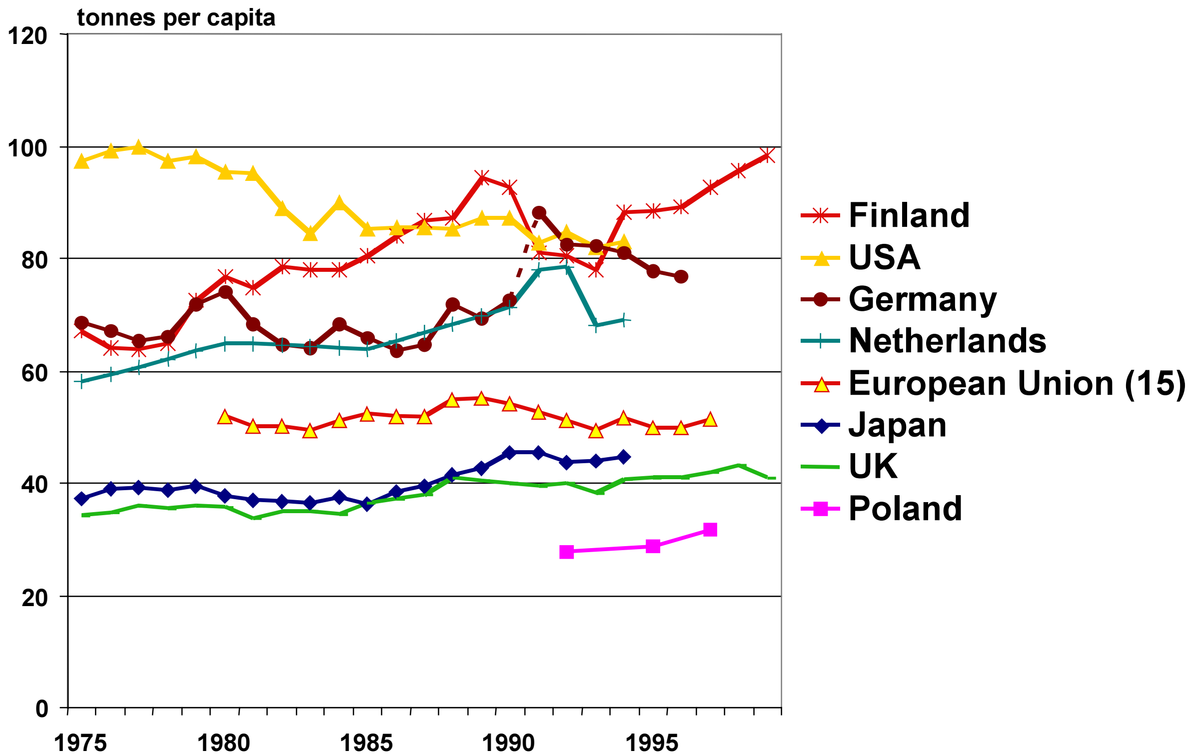
[14] The TMR per capita trend of the UK is influenced by incomplete statistical data on imported precious metals and diamonds especially during the early study period (Bringezu and Schütz 2001c).

There are some differences in the methods for estimating the TMRs across countries. However, detailed analysis suggests that these differences have a rather small impact on the results. Other factors such as industrial structure or the openness of an economy towards international trade are likely to be much more important. Extensive research into the factors that explain why the levels and movements of TMR differ across counties is beyond the objectives of this study. A first step towards a better understanding of these factors is the analysis of the detailed components of TMR, presented below and in section 3.3 (see also the Eurostat Guide, pages 37-43).

TMR per capita of the EU was remarkably constant through the study period. In the early 1990s it came close to the values for Japan. Only the UK and Poland had still lower TMR per capita. However, three Member States of the EU, Finland, Germany and the Netherlands turned out as more resource intensive economies, requiring up to two times the EU total material resources per capita.

In order to compare the main components of the TMR between the EU-15 and other countries major material flows were differentiated which are fossil fuels, minerals (for construction and other industrial use), metals, biomass, excavation (and dredging) and soil erosion. More than two third (72%) of the EU TMR in 1995 are represented by resource flows of fossil fuels, metals and minerals (FIGURE 3.5).

Figure 3.4: TMR per capita in EU-15 and international comparison.



Fossil Fuels

On the per capita average the EU extracted 15.1 t fossil fuel resources in 1995. Energy carriers plus associated hidden flows amounted to 30% of TMR. The UK in 1995 extracted 13.7 t fossil fuel resources and energy carrier plus hidden flows amounted to 36% of TMR. Thus, fossil fuel resource requirements of the UK are very similar to the EU-15 average. Due to a lower use of energy and a reduced amount of coal use the EU level is only 46% of the 1994 fossil fuel resource requirements of the USA. Of the countries studied, Finland performed with the lowest fossil fuel resource requirements. Though the total TMR per capita of Poland was only 34% that of Finland, the Polish fossil fuels requirements with 12.2 t/cap[15] exceeded the Finnish ones by 14%. The Polish per capita fossil fuel requirements were quite similar to Japan, the UK and the EU-15.

Minerals

Mineral resources are mainly used for construction. This use accounts for about 22% of the total materials requirement in the EU including those for industrial use. Production in the EU demands 10.8 t/cap. The requirements are almost the same in EU-15 and in the USA. From the EU Member States studied, Germany and Finland had the highest rate of minerals extraction due to the production of sand and gravel as well as natural stones in Germany, and the extraction of gravel in Finland. The German values are twice those of EU-15 as a whole and 2.6 times those of the UK, due to construction activities for houses and infrastructures which still rely on high inputs of minerals for concrete. The lowest requirements for minerals are shown for the Netherlands.

Metals

Resource requirements for metals are 10.2 t/cap in the EU in 1995. The level is similar to USA in 1994 (9.4 t/cap) and the Netherlands in 1994 (10.6 t/cap). A significantly higher level is reached in Finland (21.5 t/cap) where metal manufacturing still represents a relevant element of industrial production. In comparison, the metal resource requirements of Japan in 1994 were 1.6 times lower than those of EU-15 in 1995.

Biomass

Biomass accounts for 6 t/cap of the TMR of the EU in 1995 which is about 12%. Similar values are found in the USA with 6.2 t/cap biomass which represents 7% of TMR in the U.S. in 1994. Most of the biomass stems from agriculture. However, Finland provides a twofold exception. First, the input of biomass amounts to 23.5% of TMR, and second, the biomass is dominated by forestry cuts which also represent a significant basis for the Finnish export industry. Compared to the EU-15 as a whole, the proportion of regrowing resources in Finland is 2 times higher.

Excavation and dredging

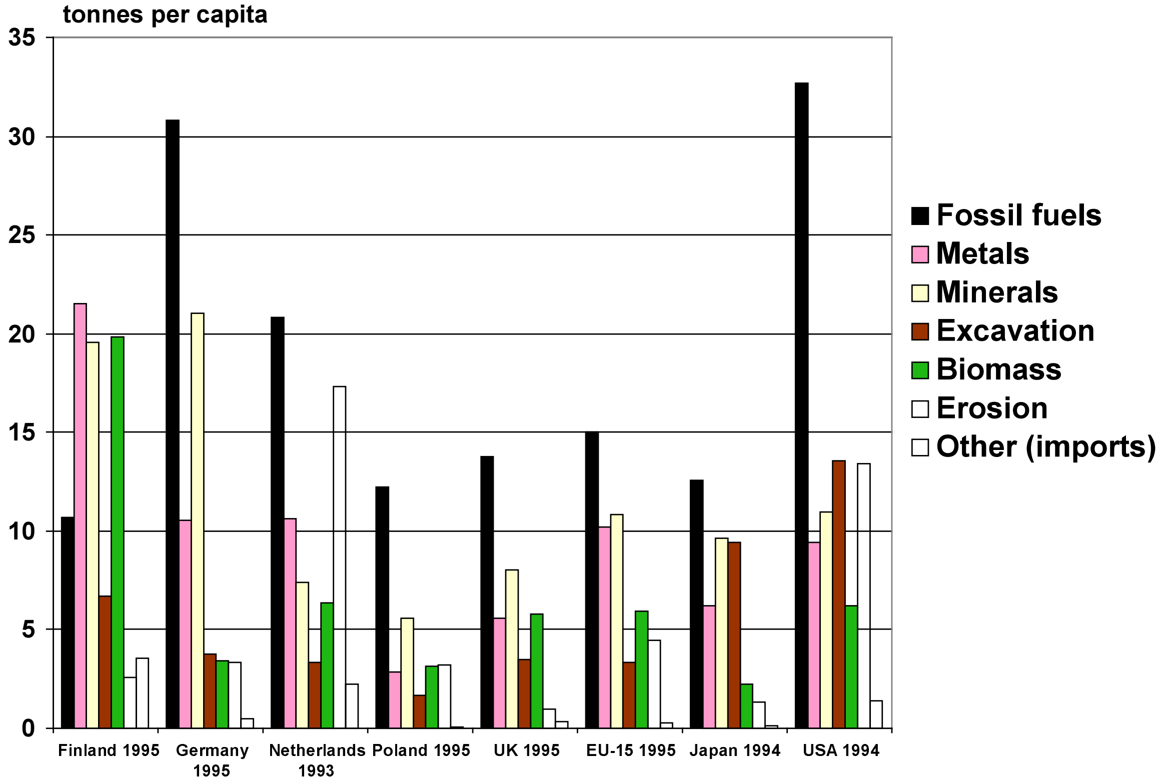
Soil excavation for constructions and dredging amounts to about 3.4 t/cap or 6.7% of the TMR of the EU in 1995. With the exception of Finland (6.7 t/cap and 8%) the order of magnitude is similar to per capita values of single European countries. Japan (9.4 t/cap and 23%) and the USA (13.6 t/cap and 15.5%) have considerably higher material flows by excavation and dredging.

Erosion

Erosion of agricultural fields in the EU is about 9% of TMR. This level is much lower than in the USA where it contributes about 15.3% to the TMR. In the USA this problem has been reduced significantly by policy programmes but still exceeds the EU-15 level by 3 times. From the Member States studied only the Netherlands are clearly above the average. This reflects the high amount of agricultural imports mainly from non-European countries. Products such as coffee and cocoa which are traded and processed in the Netherlands are associated with high levels of erosion in countries of the South.

[15] More than four fifth (81.1%) of the Polish energy input equal to DMI (indigenous production plus imports) in 1995 were for domestic consumption (TPES, in energetic units).

Figure 3.5: TMR per capita composition of EU-15 and international comparison.



3.3. Domestic and foreign components of TMR of the EU

From 1980 to 1997 domestic extraction in total accounted for 61% to 73% of TMR. Higher shares were recorded during the first part of the study period, they were decreasing since 1986 to the lowest share of 61% in 1997.

From 1980 to 1989 the domestic part of TMR of the EU had increased from 12.6 to 13.8 billion tonnes which is about 35 to 38 tonnes per capita (FIGURE 3.6). Afterwards, the domestic TMR of EU-15 had declined until the end of the period to 11.7 billion tonnes or 31 tonnes per capita in 1997. This decline was mainly due to fossil fuel resources which declined from 5.5 billion tonnes in 1989 to 3.4 billion tonnes in 1997, i.e. by 38%. Over the entire study period 1980 to 1997 the share of fossil fuels (incl. hidden flows) in domestic TMR had declined from around 40% to 29%.

The total domestic extraction of minerals varied between 3.4 and 4 billion tonnes during 1980 to 1997. Levels in the 1990s were higher than before. Since 1994, the share of minerals in domestic TMR was higher than that of fossil fuels reaching 33% in 1997.

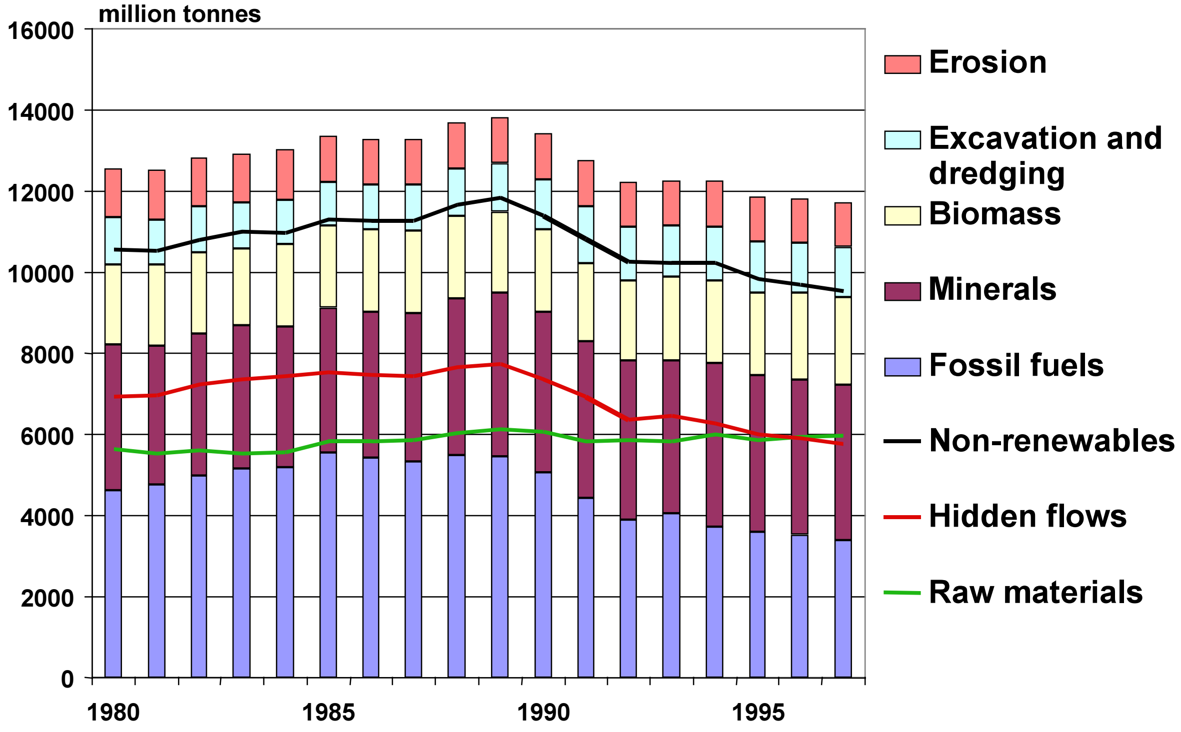
Biomass ranks third contributing around 15% to 19% to domestic TMR (1.9 to 2.2 billion tonnes). Just as for minerals, the share of biomass increased over the study period until 1997. Soil erosion contributed between 1.1 and 1.2 billion tonnes to domestic TMR. So, between 50% and 62% the mass of resource requirements for domestic biomass were additionaly required as agricultural soil lost. The share of erosion in domestic TMR was fairly constant over time (around 8% to 10%).

Excavation and dredging contributed 1.1 to 1.4 billion tonnes to domestic TMR. The share of excavation and dredging increased to 10%-11% in the 1990s as compared to 8%-9% in the 1980s.

Altogether, the share of non-renewables in domestic TMR of EU-15 declined from about 84%-85% in the 1980s to 81% in 1997. This was mainly favoured by a reduction of domestic hidden flows lowering their share of domestic TMR from around 55% to 49%. Consequently, the resource efficiency of domestic raw material extraction in EU-15 had improved during the 1990s. Much of this development resulted from a decline in lignite production and was a consequence of the German re-unification. The energy supply of the former GDR had been heavily dependent on domestic lignite extraction[16]. After 1990 a significant amount of the old fashioned production facilities in the Eastern part of Germany were closed. The German production of lignite went down from 433 million t in 1985 to 177 million t in 1997, and its contribution to EU-15 production volume was reduced from 87% to 72%. In Germany lignite production gave rise to political debate and was highly controversial due to continuous planning which led to the resettlements of entire villages located above the deposits.

In 1997 the extraction of lignite was still associated with 22% of the domestic TMR of EU-15. The main producers are Germany, Greece, and Spain with 72.5%, 23.1%, and 3.5% of EU-15 lignite production, respectively (together: 99%). These countries are also extracting 99.5% of the overburden linked to lignite production.

Figure 3.6: Main material groups of domestic TMR EU-15 1980-1997.



In 1997 the up-stream resource extraction associated with imports of EU-15 was at least 7.5 billion tonnes or 20 t/cap (FIGURE 3.7). This contributed 39% to TMR. The major components are metal and energy resources with 55.9%, and 27.9% respectively. Biomass imports amount only to 2.1%, although they are linked to erosion with 7.6% of foreign TMR. The re-growing proportion of foreign TMR is 2.1%, compared to 18.5% of domestic TMR. Thus foreign TMR contributes especially to the depletion of non-renewable resources.

[16] From 1980 to 1989 lignite mining in the former GDR contributed between 19% and 22% to the domestic TMR of EU-15.

From 1983 to 1997 foreign TMR per capita in EU-15 rose from 13 to 20 tonnes per capita. The increase was mainly caused by imported minerals, especially by resource requirements for precious metals[17].

From 1995 to 1997 foreign TMR grew by 10% to 20 t/cap. Within these three years the import of precious metal ores increased by 51%. As a result of the scarcity of precious metals, the extraction waste of mining is extraordinarily high. In general, the world average hidden flow factor of gold mining has been applied to account for the resource requirements of that group (comprising gold, platinum, rhodium, palladium, iridium, osmium and ruthenium). The value of 259,010 tonnes per tonne represents a minimum estimate also for other precious metals such as platinum. In 1997, resource flows of precious metals contributed the highest amount (75.2%) of metal resource extraction for imports to EU-15 (it was 63.8% in 1995 and 72.5% in 1996). In comparison, resource extraction for iron and copper ore imports in 1997 ranked second and third with 15.7% and 3.4%, respectively.

The calculated order of magnitude of 1 to 1.8 billion t resource flows for precious metal import volume of 3,700 to 5,600 t between 1995 to 1997 provides ample evidence that more information is needed on the specific material flows and the environmental impacts of precious metal mining induced by manufacturing and investments in EU-15. Virtually the entire silver is used for fabrication; most of the platinum is required for manufacturing sectors, especially for use in catalytic converters; usually most of the global gold production is required by manufacturing sectors, predominantly by the jewellery industry, but high quantities are also demanded for governmental and private hoarding which varies strongly from year to year.

From 1995 to 1997 the import of electricity to EU-15 increased by 8.9%. Based on data on standard power plants and the UCPTE mix (Union pour la coordination de la production de l'électricité, i.e. the West-European electricity net), the resource requirements for the production of electricity amount to 1.58 kg per kWh[18]. Thus, one may calculate that the import of 177,208 GWh of electricity to EU-15 in 1997 was associated with about 280 million t of resources, i.e. 0.75 t/cap. Any increase in the import of electricity represents a shift of environmental impact. Whereas the resulting burden sharing due to global climate change may remain unaffected - if electricity production and consumption is kept constant - the burden of extracting the energy resources has to be carried by the country of origin only.

The imports of precious stones other than diamonds (2337 to 2450 tonnes from 1995 to 1997) has not yet been attributed to a certain amount of hidden flows due to insufficient data availability. However, in some cases precious stone mining may reach the hidden flow ratio of gold. The potential extent of these resource flows clearly indicates the need for further information.

Altogether, hidden flows of imports and the non-renewable resource requirements for imports increased significantly over commodities. This indicates a continuously high and even growing pressure to the environment of foreign countries which is associated with the EU economy.

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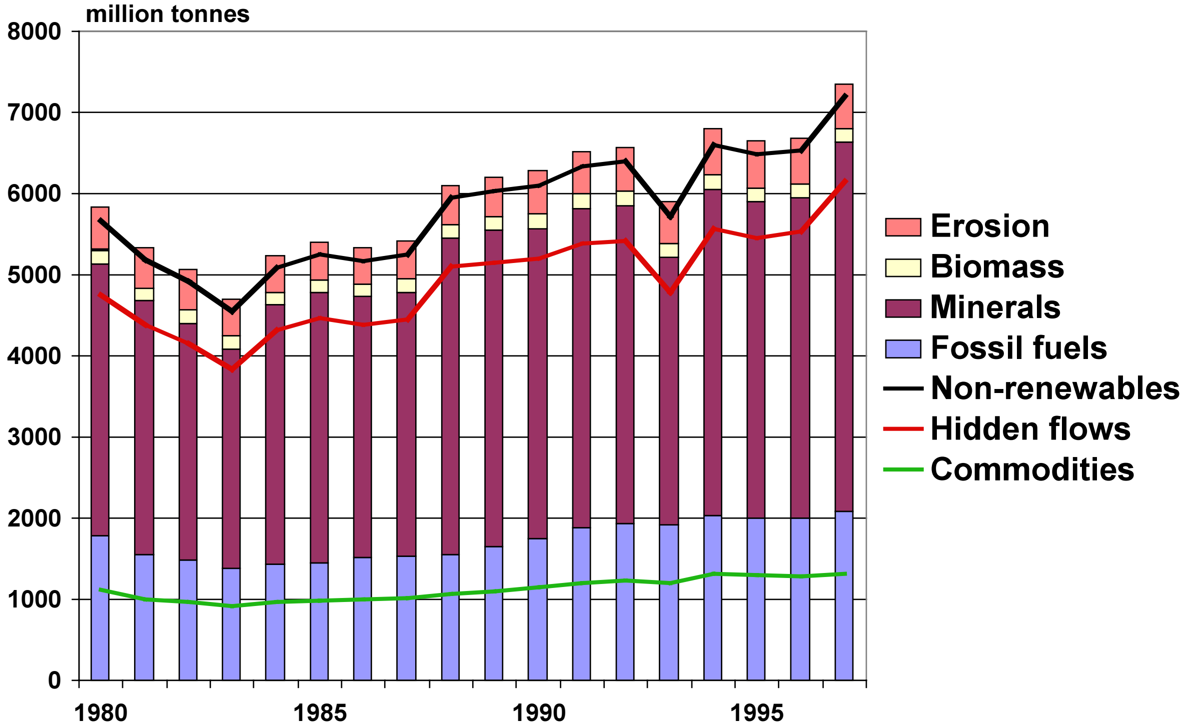
[17] Due to incomplete statistical data on foreign trade detailed import data for EU-15 were available for 1995 to 1997 only. From 1980 to 1994 EU-15 total imports of commodities (and hence, also of hidden flows) were estimated on the basis of EEC data available from foreign trade statistics. Thus, the accuracy of data on foreign material inputs is significantly higher for 1995 to 1997 than for 1980 to 1994. More details on this issue are described in the Annex.
[18] The accuracy of the material requirements of imported electricity could be substantially improved if country-specific studies of the material intensity of electricity generation based on standardised annual energy statistics were performed.

Figure 3.7: Main material groups of foreign TMR EU-15 1980-1997.



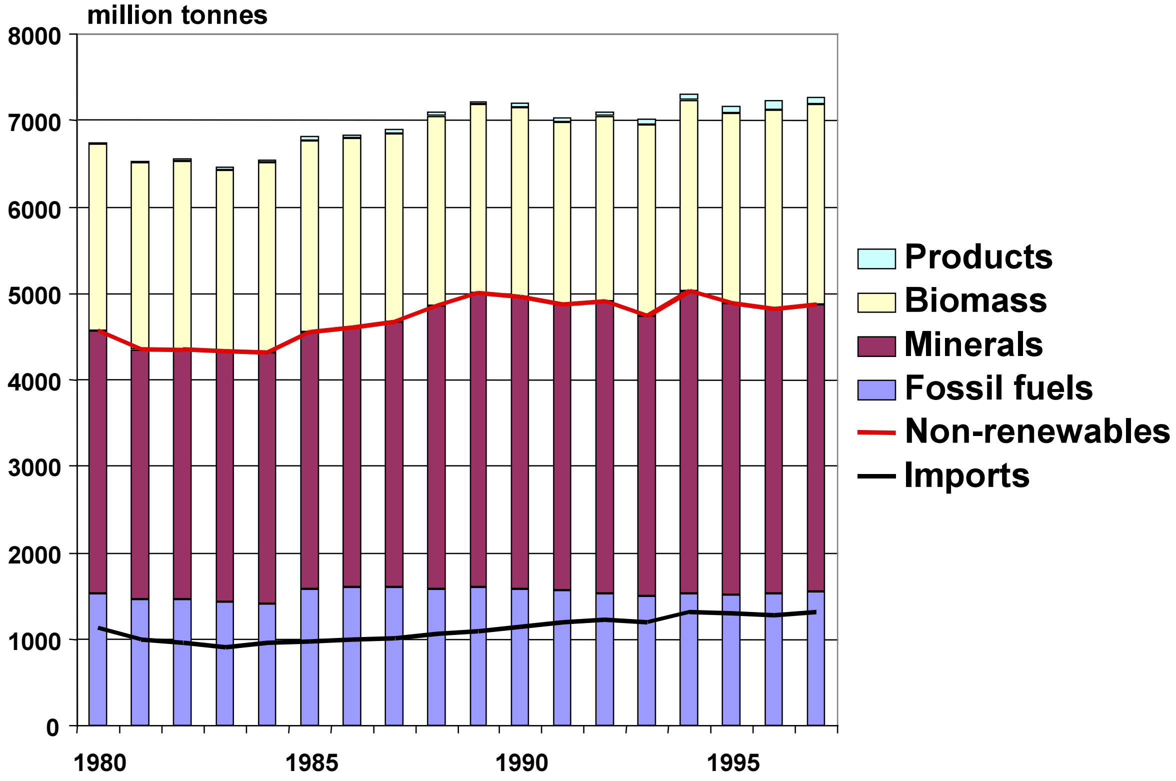
4. Direct Material Input

The part of TMR which is used for further processing is called Direct Material Input (DMI). It comprises domestic production of primary raw materials and the physical amount of the imports without hidden flows. Imported raw materials and semi-manufactured products are accounted for according to their primary materials component.

From 1980 to 1997 DMI of the EU-15 ranged from 6.5 to 7.3 billion tonnes or from 18 to 20 tonnes per capita (FIGURE 4.1). Through the nineties the level of DMI was slightly higher than during the 1980s.

Minerals, in particular construction materials, dominated DMI of the EU by 44% to 48%. Biomass ranks second with 30% to 34%. In contrast to TMR fossil fuels play a less pronounced role for the composition of DMI. Their share ranged between 21% and 24% of DMI from 1980 to 1997 (as compared with 29% to 37% in TMR). Imported products play only a minor role with 0.4 to 1.7% but with increasing tendency in the 1990s. Altogether, non-renewables accounted for about two third of the direct material input of the EU. Imported commodities contribute between 14% and 18%.

Figure 4.1: Main material groups of DMI EU-15 1980-1997.



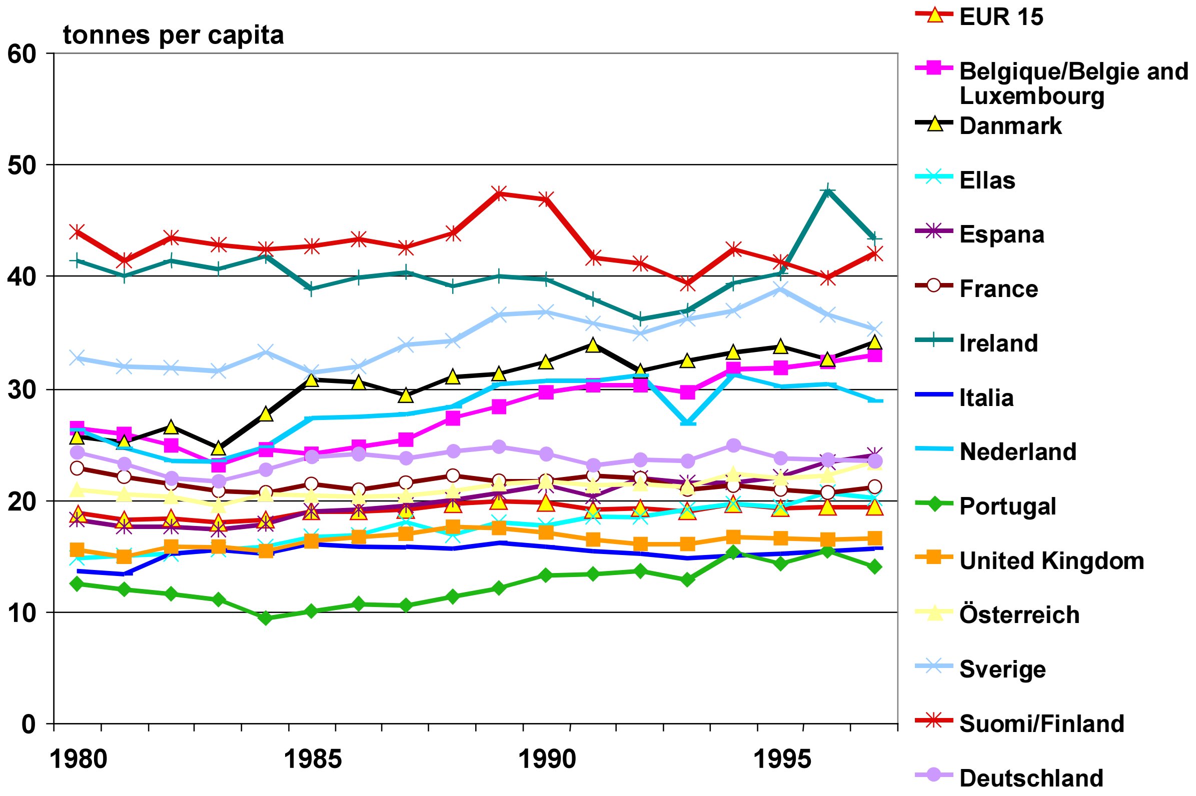
Direct material input of the EU-15 and its Member States from 1980 to 1997 was compared (FIGURE 4.2). With respect to the per capita level of DMI the following groups may be distinguished (TABLE 4.1).

Among the EU Member States only Finland showed a slightly declining direct material input per capita trend from 1990 to 1997. Thus, there is no sign of an absolute delinking of direct material resource requirements from economic development in the EU. The trends clearly show that these economies so far depend on a at least constant material input. With extraordinarily high and still increasing levels of DMI per capita especially Ireland and Belgium and Luxembourg are challenged to reduce their dependence from direct material resource requirements while promoting economic growth in the future.

TABLE 4.1: DMI per capita maximum levels and trends in EU.

	Maximum values of DMI 1980-97				
	up to 20 t/cap	21-30 t/cap	31-40 t/cap	over 40 t/cap	Trend since 1990
EU-15	X				→
Italy	X				→
Portugal	X				↗
UK	X				→
Greece		X			↗
Spain		X			↗
France		X			→
Austria		X			→
Germany		X			→
Belgium and Luxembourg			X		↗
Denmark			X		→
Netherlands			X		→
Sweden			X		→
Ireland				X	↗
Finland				X	↘

Figure 4.2: DMI per capita in EU-15 and Member States, 1980-1997.



5. Material productivity

When the economic performance is measured in terms of GDP, the relation to various components of TMR can indicate important aspects of the interlinkage of economic activities and resource requirements.

Within EU-15 the UK (17 t/cap), Italy (16 t/cap) and Portugal (14 t/cap) had the lowest level of DMI (Table 5.1). In 1997 Ireland and Finland used the highest amount of DMI with 43 and 40 t/cap, respectively. From 1980 to 1997 the DMI per capita of the EU as a whole had increased by 3%. Slightly declining trends of DMI per capita from 1980 to 1997 could be observed for Germany and France (around 3% and 7%, respectively, less than in 1980). A significant increase, however, took place in Greece (plus 36%), Denmark (plus 33%), Spain (plus 32%), Belgium and Luxembourg (plus 25%), Italy (plus 14%), and Portugal and Austria (both plus 12%).

In 1997 the highest material productivity of DMI was achieved by Italy with 1.03 ECU GDP gained per kg DMI followed by the UK with 0.88 ECU/kg (Table 5.1).

More economic wealth could be provided from less use of direct materials inputs (DMI) in 1997 compared to 1980. In the EU as a whole the relation of GDP to DMI of EU-15 increased by 31% from 1980 to 1997. While DMI has remained rather constant, a relative decoupling can be monitored based on significant economic growth. Between 1980 and 1997, Ireland had by far gained the highest increase in DMI materials productivity with plus 113%, followed by Germany with plus 51%[19]. The only country with a negative development of the productivity of its direct material inputs was Greece with minus 11%.

[19] It has to be noted that German data are strongly effected by the re-unification in 1990. Before, data for Germany represent the total of two distinct economies in West-Germany and in the former GDR.

The increase in resource productivity is not necessarily associated with a reduction in resource requirements. However, the absolute burden to the environment can only be diminished by an absolute reduction in the physical flows which are indicated by DMI and TMR.

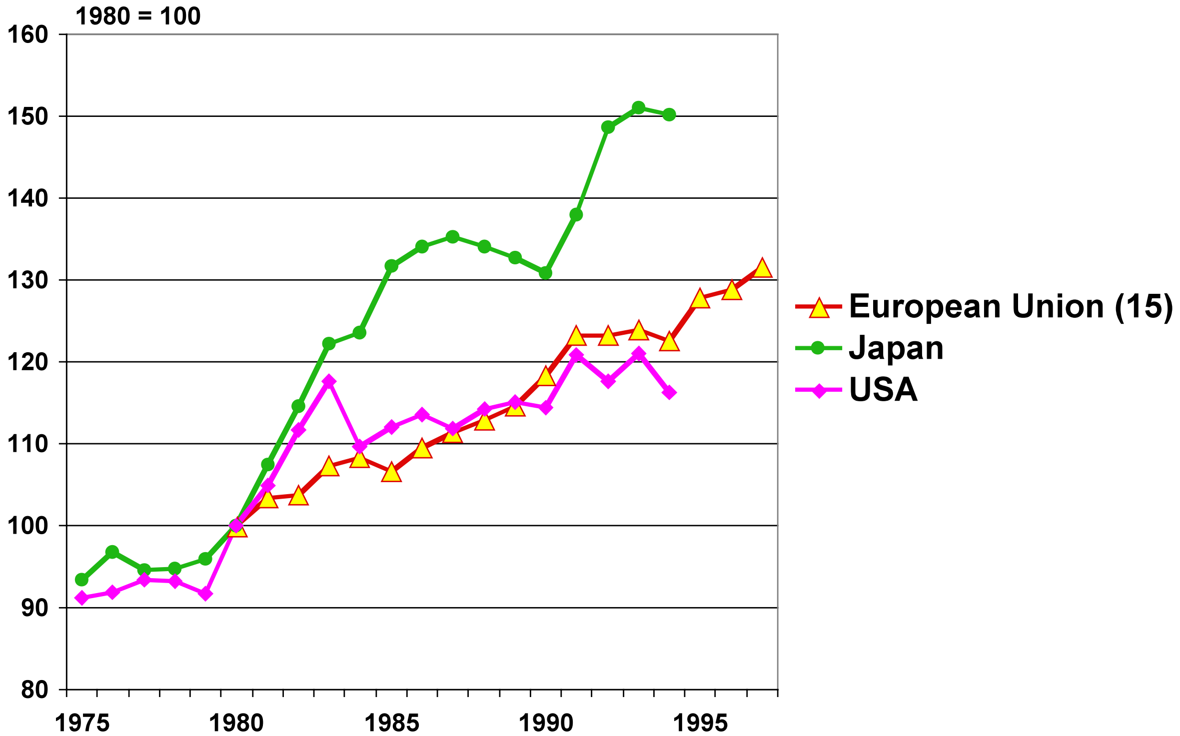
The European Union had a similar positive development of the direct materials productivity of GDP from 1980 to 1997 as the USA until 1994 (FIGURE 5.1). But compared with Japan it was significantly lower. Whereas Japan increased GDP/DMI by about 50% from 1980 to 1994, the EU reached only about 23% increase during that period.

Table 5.1: DMI and GDP in EU-15 and Member States, 1980-1997.

	t per capita 1997	ECU per kg 1997	Change from 1980 to 1997 t per capita	Change from 1980 to 1997 ECU per kg
Ireland	43	0.36	5%	113%
Finland	40	0.55	0%	35%
Sweden	35	0.61	8%	12%
Denmark	34	0.68	33%	12%
Belgium and Luxembourg	33	0.53	25%	6%
Netherlands	29	0.59	1%	31%
Spain	24	0.47	32%	12%
Germany	24	0.75	-3%	51%
Austria	23	0.76	12%	20%
France	21	0.82	-7%	34%
Greece	20	0.34	36%	-11%
European Union (15)	19	0.81	3%	31%
UK	17	0.88	6%	31%
Italy	16	1.03	14%	16%
Portugal	14	0.45	12%	40%

Note: GDP is given in ECU at 1990 constant prices (Source: Eurostat)

Figure 5.1: GDP/DMI in EU-15 and international comparison, 1980-1997.



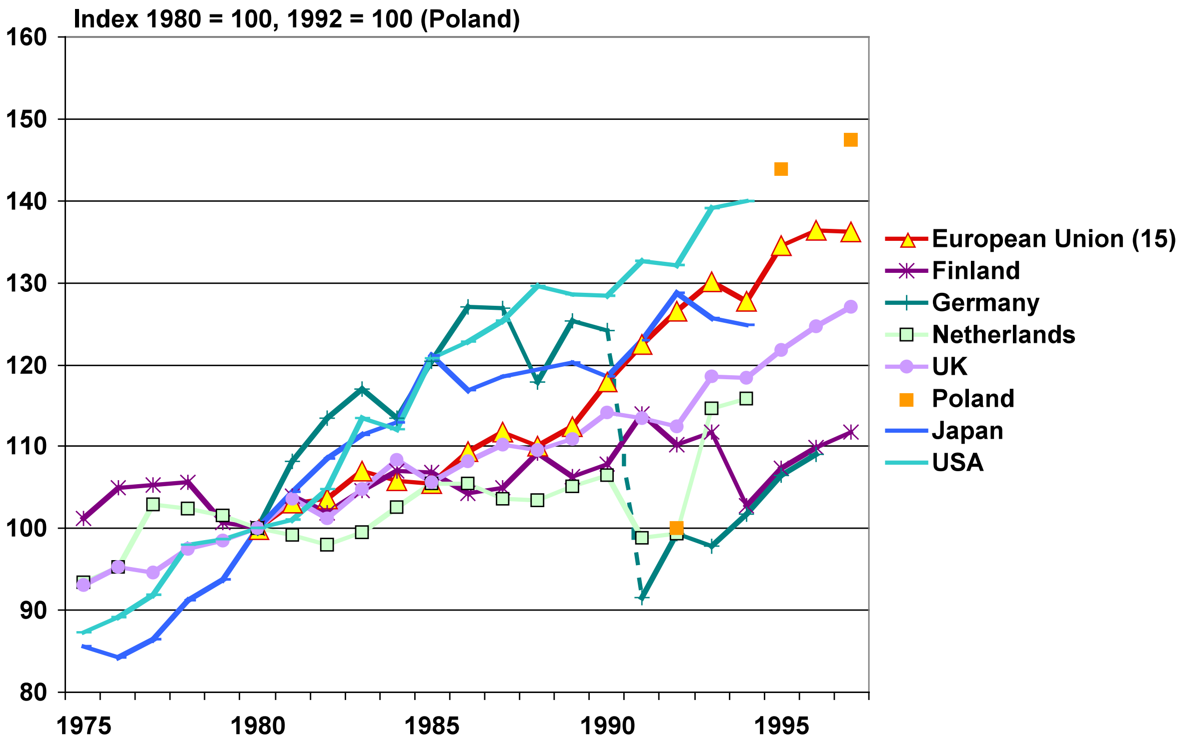
Is economic activity becoming decoupled from natural resource use in terms of total materials requirement? This was one of several questions raised in the first international resource flows study for USA, Japan, the Netherlands and Germany (Adriaanse et al. 1997). Meanwhile, more comparisons are possible based on TMR studies for the EU-15, Finland, Poland and for the UK (FIGURE 5.2).

The overall picture seems to indicate a general tendency towards a decoupling of TMR and GDP. A continuous decoupling can be observed for USA, Japan and EU-15. The German situation is characterised by the reunification[20]. Before 1991 GDP/TMR in West-Germany increased due to constant TMR and growing GDP. In 1991, after the inclusion of the former East Germany, the GDP/TMR index decreased significantly compared with the West-German level in 1990, but afterwards it increased again to levels reached in West-Germany during the mid 1980s. In contrast, GDP/TMR of the Netherlands and Finland showed a rather constant trend over the study period indicating that economic growth and material use was still coupled in those two economies.

The strongest decoupling of TMR and GDP since 1992 was recorded for Poland between 1992 and 1997 due to the country's economic transformation associated with increases in GDP of 27% while TMR had increased by „only" 15% over the same period.

Altogether, a decoupling of economic growth and total material requirement took place in the UK from 1975 to 1999 which led to a significant increase in total resource productivity.

Figure 5.2: GDP/TMR in EU-15 and international comparison, 1980-1997.



[20] It has to be noted that TMR of Germany could so far only be accounted for in time series for West Germany 1975 to 1990 (Adriaanse et al. 1997) and for the re-united Germany 1991 to 1996 (Adriaanse et al. 1997, Bringezu and Schütz 2001a). Only the domestic part of TMR for the re-united Germany was for the first time accounted for in the present study from 1980 to 1997 as a constituent of the TMR of EU-15.

6. Total Domestic Output

Total Domestic Output (TDO) is the aggregate measure of domestic processed output (material outflows from the economy) plus domestic hidden flows (which do not enter the economy). It represents the total quantity of material outputs and material displacement within national borders and is the best proxy indicator of overall *potential* output-related environmental impacts in each country. Internationally comparable data for total domestic outputs (TDO) and domestic processed outputs (DPO) by Austria, Japan, Germany, the Netherlands and the USA were first published by Matthews et al. (2000). TDO of the UK was determined by Bringezu and Schütz (2001c).

TDO of the EU-15 declined from 1990 to 1996 from 11.8 billion tonnes to 10.3 billion tonnes which is 32 to 27 t/cap (FIGURE 6.1). This reduction was mainly due to declining unused extraction which was largely the result of the German re-unification in 1990 and subsequent reductions in lignite mining in the former East Germany. Consequently, the share of unused extraction in TDO declined from 43% in 1990 to 35% in 1996.

The second largest component of TDO are emissions of carbon dioxide. They remained fairly constant from 1990 to 1996 and their share in TDO rose from 29% to 34%. Also other emissions to air remained more or less on the same level over that period at a share of around 2% of TDO. The Domestic Processed Outputs (DPO) remained constant from 1990 to 1996 and their share in TDO rose from 38% to 43%.

In comparison with socio-economic data for population and GDP, the relative developments of material outputs to the environment as DPO and TDO, domestic hidden flows or indirect flows, dissipative flows, waste landfilled, NO_2, SO_2 and CO_2 are shown in FIGURE 6.2. From 1980 to 1997 population grew by about 5%. DPO remained almost constant wheras TDO decreased significantly, mainly due to reduced domestic hidden flows.

The most obvious change occured with sulphur dioxide which was reduced by 65% of the level of 1980 in 1997. In contrast, carbon dioxide emissions remained rather constant. Also nitrous oxide emissions remained constant until 1992 and then declined by about 13% until 1997.

The data show that the increase of GDP, which rose by about 42% during the study period, was not coupled with a corresponding increase of material output flows. An absolute delinking of economic growth was especially expressed for sulphur dioxide due to strong efforts in end-of-pipe technology. Carbon dioxide emissions, however, remained constant leaving the challenge to achieve absolute decoupling from GDP increase in the future.

Figure 6.1: TDO by main material groups: EU-15 1990-1996.

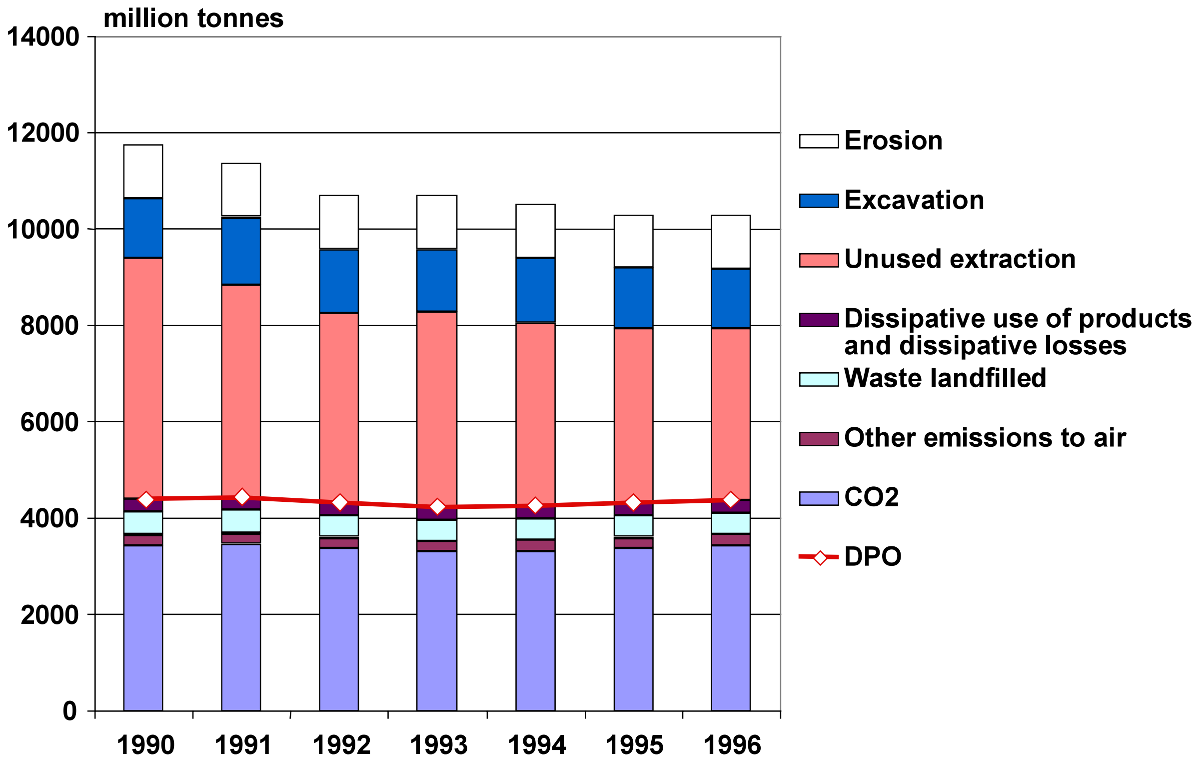
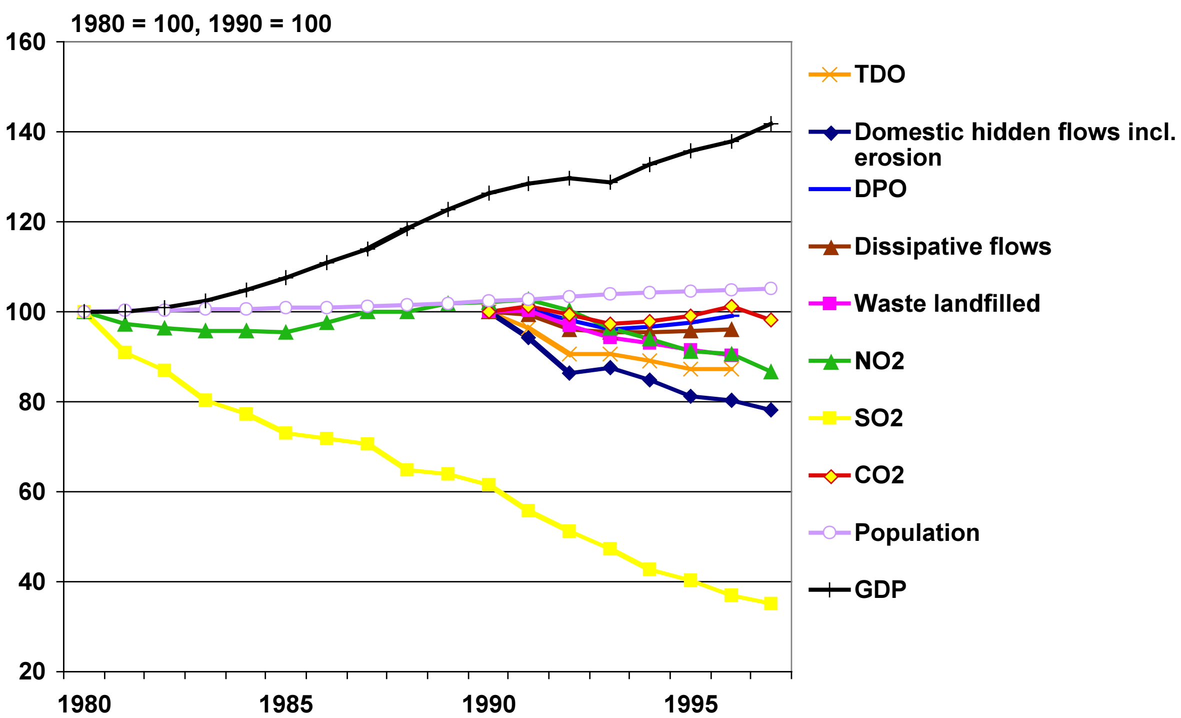
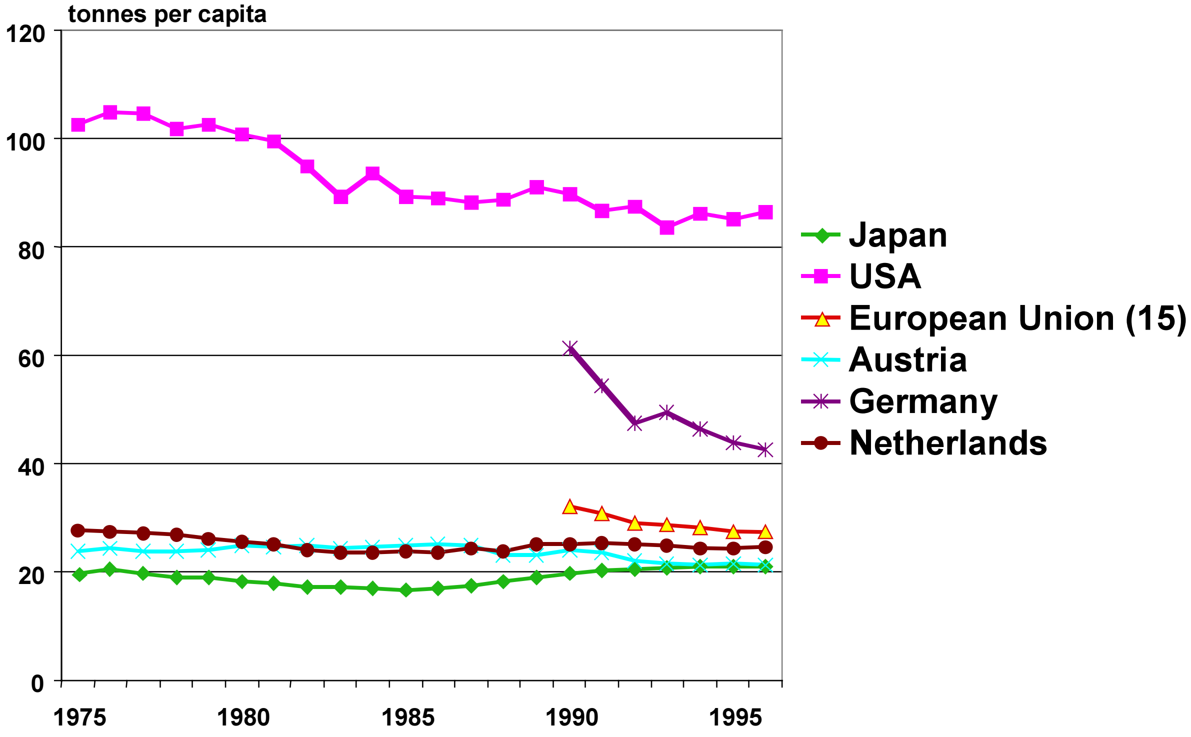


Figure 6.2: Population, GDP, material ouputs to the environment and respective indicators: EU-15 1980-1997, indexed.



In an international comparison 27 t/cap TDO of the EU in 1996 was slightly higher than in Japan with 21 t/cap (FIGURE 6.3). Among the EU Member States studied only Germany had significantly higher TDO per capita, e.g. 43 t/cap in 1996. The U.S. exceeded by far TDO of the other countries, its level in 1996 (86 t/cap) was about 3.1 times the level of EU-15.

Figure 6.3: TDO per capita in EU-15 and international comparison.



Within the EU in 1996 Portugal and Italy had the lowest TDO per capita at 16 tonnes, about 60% the level of EU-15 as a whole (27 t/cap) (TABLE 6.1). Higher levels of TDO per capita were recorded for Finland (38 t/cap), Germany (43 t/cap) and Greece (67 t/cap).

From 1990 to 1996 the EU achieved a 15% reduction in per capita TDO. The strongest contribution was made by Germany with minus 31% per capita TDO. Among the other Member States especially Denmark (plus 22%) had increased the TDO per capita.

Table 6.1: TDO per capita in EU-15 and Member States, 1990-1996.

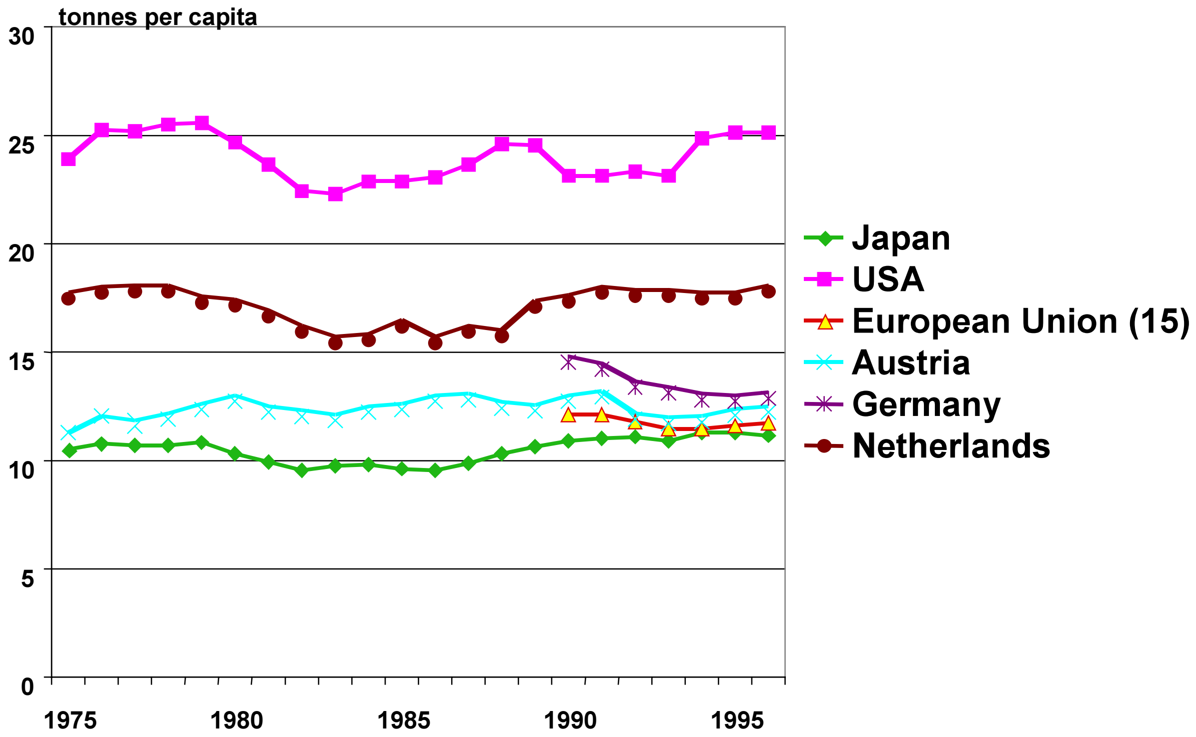
TDO		Change from 1990 to 1996
	t per capita 1996	t per capita
Greece	67	4%
Germany	43	-31%
Finland	38	-7%
Spain	28	-4%
European Union (15)	27	-15%
Denmark	26	22%
Netherlands	25	-2%
UK	23	-7%
Ireland	21	8%
Austria	21	-12%
Sweden	20	-4%
Belgium and Luxembourg	19	5%
France	18	-6%
Italy	16	-4%
Portugal	16	6%

7. Domestic Processed Output

Domestic processed output (DPO) comprises solid wastes, and liquid and gaseous emissions and discharges; these flows are partially recorded in official national statistics, though many individual flows are missed.

The DPO indicator was found to be less variable than TDO in USA, Japan, Austria, Germany and the Netherlands, because it reflects the throughput of economic activities and technological processes similar for all countries and excludes the highly variable hidden flows associated with primary production (Matthews et al. 2000). This matches results for EU-15. On a per capita basis, the quantity of domestic processed output generated in the EU-15 was almost constant from 1990 to 1996 at 11 to 12 t/cap (FIGURE 7.1). This was slightly higher than DPO per capita in Japan at 11 t/cap, and it was only about half of DPO per capita in the USA at 23 to 25 t/cap.

Figure 7.1: DPO per capita in EU-15 and international comparison.



Among the Member States of the EU, Finland in 1996 had a DPO per capita even higher than that of the U.S. at 27 t/cap. The second highest DPO per capita at 20 t/cap was recorded for the Netherlands, the third highest for Denmark (17 t/cap). Seven Member States had a lower DPO per capita than the EU average (12 t/cap), among them four countries in the South, i.e. Greece, Italy, Spain, and Portugal with the lowest value of all Member States at 6 t/cap.

From 1990 to 1996 DPO per capita of the EU had remained almost constant (minus 3%). Remarkable changes of DPO per capita had occured in Denmark (plus 29%) and in Germany (minus 11%).

DPO constituted a low part of TDO in Greece with 17% in 1996. In contrast, about 84% of the total material outputs to the environment were domestic processed outputs in Belgium and Luxembourg in 1996. In EU-15 DPO was almost half (48%) of TDO per capita in 1996.

Table 7.1: DPO per capita in EU-15 and Member States, 1990-1996.

DPO	t per capita 1996	Change from 1990 to 1996 t per capita	DPO t/cap as % of TDO
Finland	27	1%	72%
Netherlands	20	3%	75%
Denmark	17	29%	72%
Belgium and Luxembourg	15	4%	84%
Ireland	14	8%	73%
Germany	13	-11%	32%
Austria	13	-4%	59%
European Union (15)	12	-3%	48%
UK	11	5%	50%
France	11	-3%	73%
Greece	10	2%	17%
Italy	10	-0%	69%
Sweden	9	4%	50%
Spain	8	4%	44%
Portugal	6	12%	67%

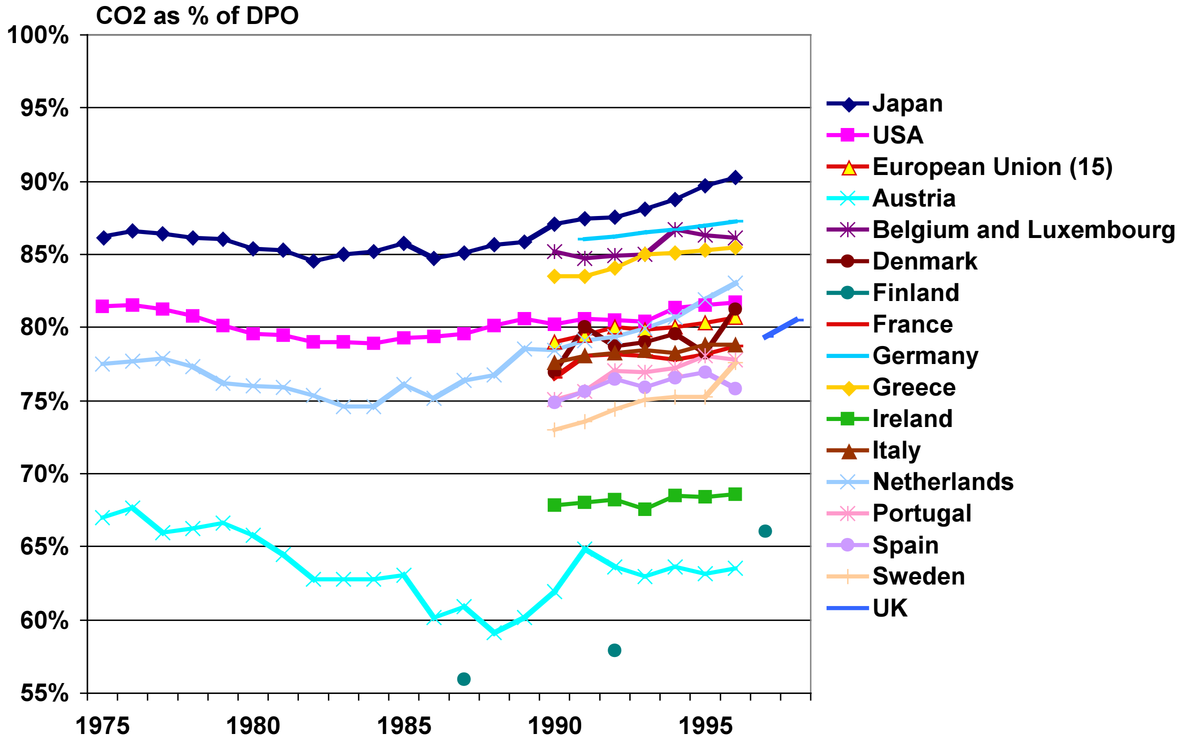
Carbon dioxide from fossil fuel combustion and industrial processes accouted for the major part of domestic processed outputs from 1975 to 1998 in USA, Japan and the EU as a whole and its Member States (FIGURE 7.2). The range of CO_2 as percent of DPO was from 55% to 90%. Japan was at the upper end increasing its use of the atmosphere for outputs to the environment from 85% to 90% from 1975 to 1996. Only slightly lower ranged Germany, Belgium and Luxembourg and Greece at around 85%.

The EU as a whole released around 80% of its DPO as CO_2 to the atmosphere with a slightly increasing tendency from 1990 to 1996. This was similar to the U.S. and most of the EU Member States ranging between 75% and 83%. Ireland and Austria had significantly lower shares of CO_2 in DPO at around 68% and 64% respectively.

The percentages of CO_2 emissions in DPO were relatively constant to slightly increasing over time in most of the study countries. Finland was an exception: its share was the lowest in 1987 with 56% but it increased to 58% in 1992 and to 66% in 1997. Obviously, despite improvements in energy efficiency fossil fuels have maintained or even increased their dominance in the material outflows of industrial economies.

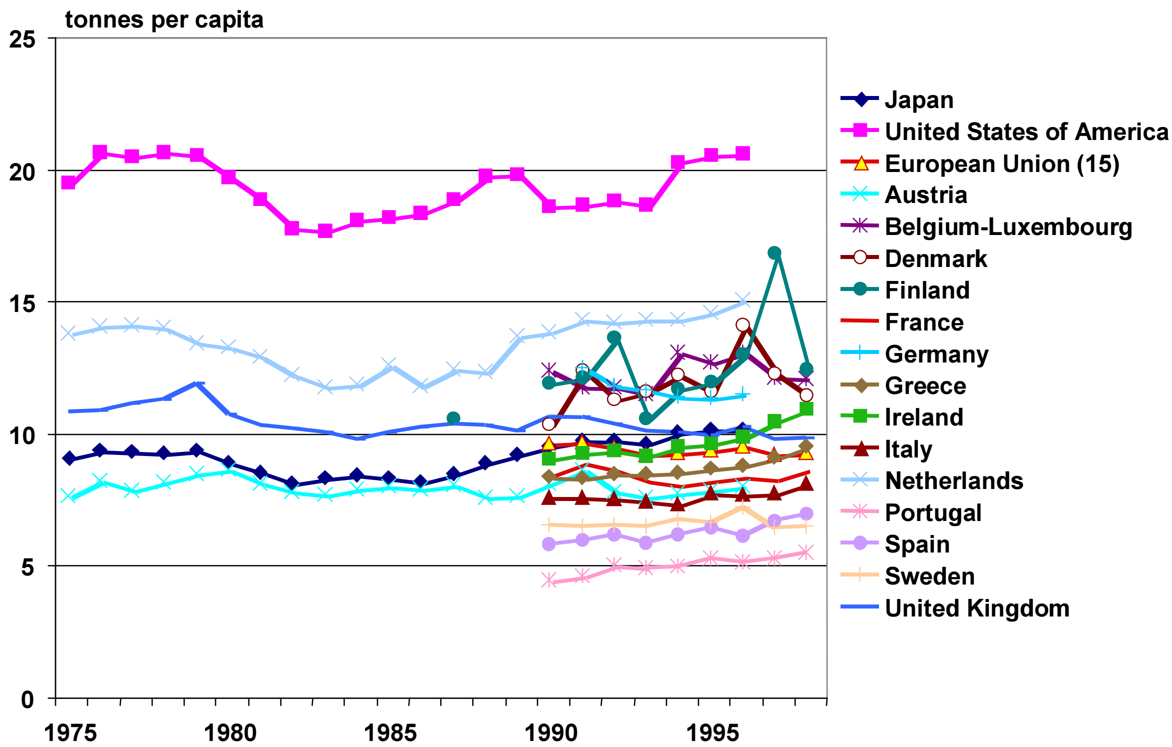
In per capita terms the U.S. is the highest emitter of carbon dioxide. From 1975 to 1996 values were rather constant at around 20 tonnes per capita (FIGURE 7.3). The EU-15 average was less than half of that, about 9 to 10 tonnes per capita from 1990 to 1998. This was about the same as for Japan at 10 t/cap in the 1990s. Significantly higher per capita CO_2 emissions than for the EU average were recorded in the Netherlands, Finland, Denmark, Belgium and Luxembourg and in Germany. Lowest levels were observed in Portugal with around 5 t/cap.

Figure 7.2: CO_2 as percent of DPO: EU-15 and international comparison.



Whereas the U.S. and Japan showed increasing trends of CO_2 emissions per capita since 1990, the EU-15 as a whole had an almost constant trend. However, none of the countries showed a clear tendency towards decreasing emissions of carbon dioxide[21].

Figure 7.3: CO_2 emissions per capita in EU-15 and international comparison 1990-1998.

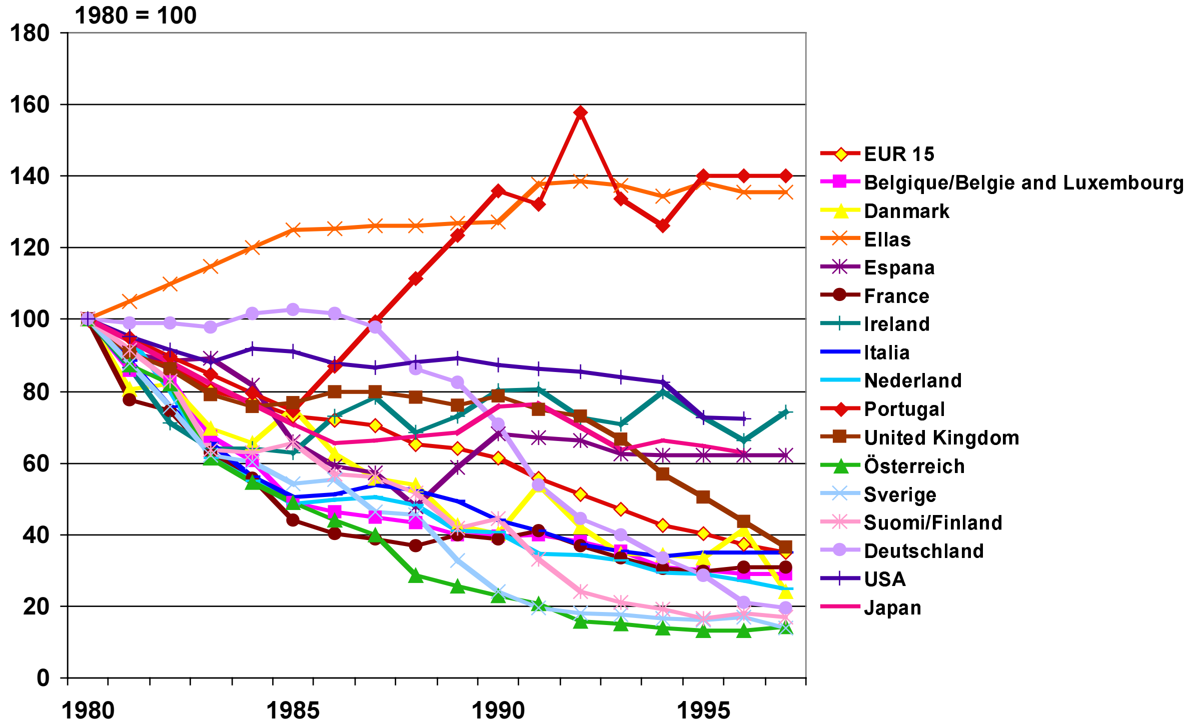


[21] The high per capita emission of carbon dioxide in Finland in 1997 was due to differences in databases. Whereas for 1987, 1992 and 1997 the original national database was used (Muukkonen 2000), data for the remaining years

In contrast to carbon dioxide the EU and most of its Member States had successfully reduced their emissions of sulphur dioxide until 1997 to 35% the level of 1980 for EU-15 as a whole (FIGURE 7.4). This was a higher reduction than the ones achieved in Japan (63% the level of 1980 in 1996) and in USA (72% the level of 1980 in 1996). Among the EU Member States, only Greece and Portugal had increased their SO_2 emissions during that period by 36% and 40% respectively.

In contrast to sulphur dioxide the EU and most of its Member States had not been as successful in reducing their emissions of nitrogen dioxide, until 1997 87% the level of 1980 for EU-15 as a whole was recorded (FIGURE 7.5). This was a similar situation than the ones observed in Japan (86% the level of 1980 in 1996) and in USA (94% the level of 1980 in 1996). Among the EU Member States, especially Portugal had increased NO_2 emissions since 1986 by a factor of about 4.2[22].

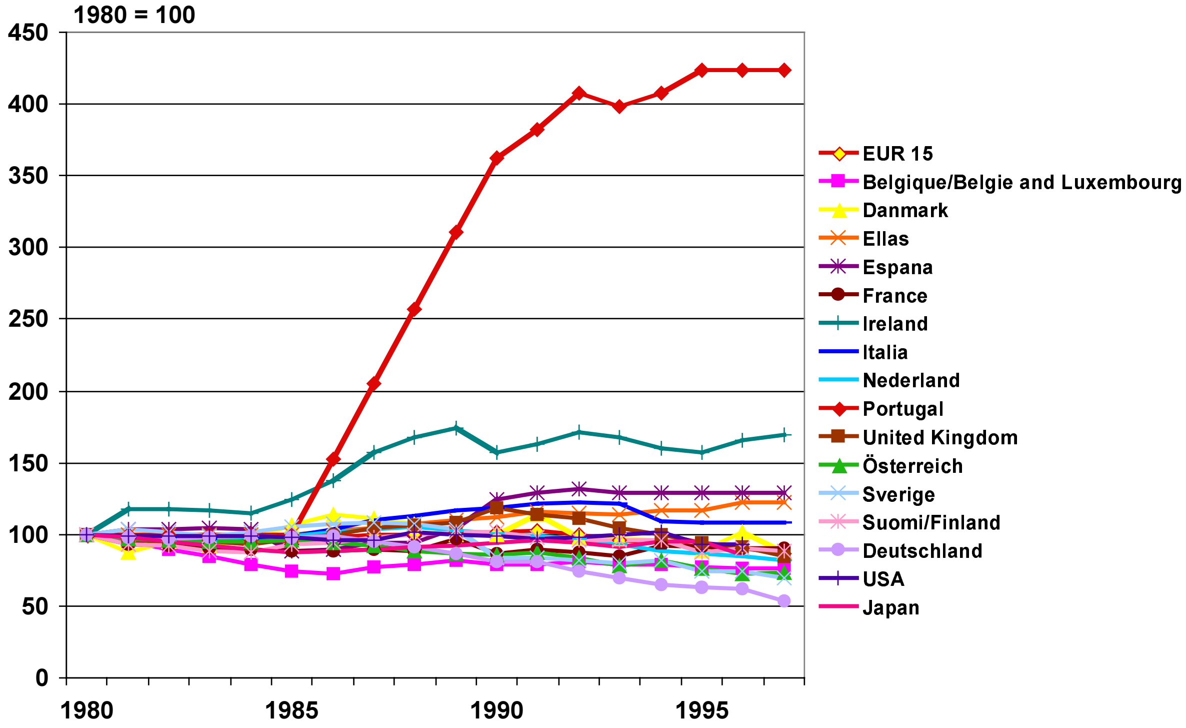
Figure 7.4: SO_2 emissions in EU-15 and international comparison 1980-1997.



from 1990 to 1998 were taken from the EEA technical report No. 41. In 1997 the original Finnish data were by 34% higher than the EEA data.

[22] Emissions of nitrous oxides in Portugal are mainly due to combustion processes (33% in 1997), road transport (45% in 1997), and other mobile sources and machinery (20% in 1997). Increased emissions are mainly due to increased road transport and emissions from combustion.

Figure 7.5: NO_2 emissions in EU-15 and international comparison 1980-1997.



8. Domestic Material Consumption

Domestic Material Consumption (DMC) measures the total amount of material directly used in an economy, excluding exports and excluding hidden flows. DMC equals DMI minus exports[23]. In other words, DMC is the annual material flow which will either remain in the domestic economy as a material addition to stock (net accumulation - NAS) or will be released to the environment as part of domestic processed output (DPO excluding oxygen). It is, thus, the direct material flow which the actors at all levels of the economy, households, firms, municipalities, politicians etc. have to manage on the national territory with respect to accumulation, recycling or final disposal in the environment. Consequently, DMC can be effectively influenced by economies implementing measures aiming at increased resource efficiency.

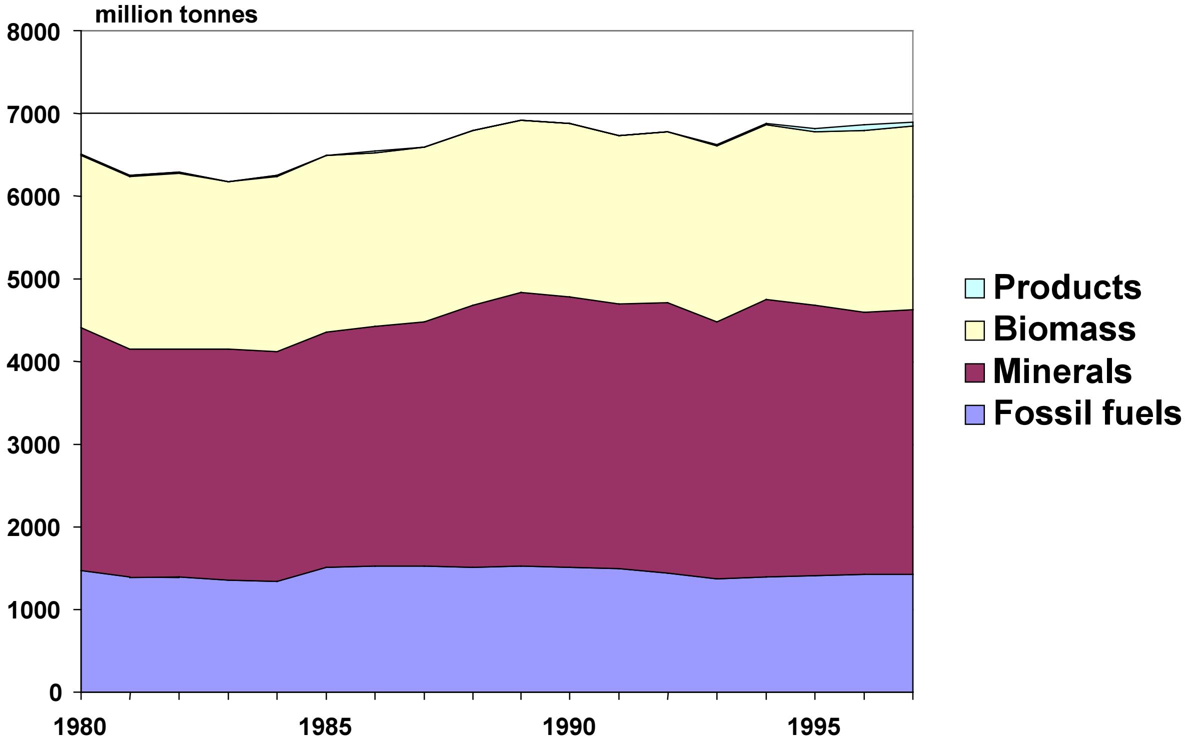
DMC of EU-15 varied from 1980 to 1997 from 6.2 to 6.9 billion tonnes or 17 to 19 tonnes per capita (FIGURE 8.1). The domestic consumption of direct materials in EU-15 was dominated by minerals, mainly for construction purposes, which took between 44% to 49% of DMC. Second ranked biomass with 30% to 34%, and third was fossil fuels with 20% to 23%. Thus, the pattern of DMC was very similar to the one of DMI (see chapter 4).

Among the Member States Belgium and Luxembourg (55% DMC of DMI) and the Netherlands (53% DMC of DMI) retained only little more than half of their direct material inputs in the economy, mainly due to their function as major entry points of imports to the EU via Antwerp or Rotterdam (TABLE 8.1). All other EU countries had significantly higher shares of DMC in DMI of more than 77%. Ireland with the highest DMC per capita in the EU had a domestic material

[23] DMC can be defined from the input side as DMI less exports, or from the output side as DPO plus NAS. In the first case, exports may contain some secondary material from recycling of stocks (e.g. scrapped cars). Hence, the part of DMI that is domestically consumed would be higher than DMC in a single year.

consumption of 93% of DMI, second ranked Spain with 91% DMC of DMI. In the EU as a whole DMC represented 95% of DMI.

Figure 8.1: DMC of EU-15 by main material groups 1980-1997.



Among the Member States of the EU Ireland had the highest DMC per capita of 40 tonnes in 1997 (TABLE 8.1). Second ranked Finland with 35 t/cap. This was almost twice the level of the EU-15 in 1997 (18 t/cap). At the lower end of the scale are Italy, the UK and Portugal with 14 t/cap, 14 t/cap and 13 t/cap, respectively. Italy showed the highest resource productivity in terms of GDP per material consumed domestically with 1.18 ECU/kg in 1997. This was 37% above the productivity in EU-15 (0.86 ECU per kg). The lowest ratio of ECU GDP gained per kg material consumed was recorded for Greece (0.38 ECU per kg) and Ireland (0.39 ECU per kg), about 45% the level of EU-15.

From 1980 to 1997 the per capita DMC of the EU-15 had hardly changed. However, in some Member States significant changes had occured. Especially Greece, Spain and Denmark increased their per capita DMC by 31%, 27% and 19%, respectively. The materials productivity of DMC increased in the EU from 1980 to 1997 by 33%. The most obvious increase occured in Ireland with 121%. Greece was the only EU Member State with a negative development of the DMC productivity from 1980 to 1997 by minus 8%.

Table 8.1: DMC per capita, GDP/DMC and DMC as % of DMI 1997, changes 1980 to 1997 in %, EU-15 and Member States.

DMC			Change from 1980 to 1997		t/cap 1997
	t per capita 1997	ECU per kg 1997	t per capita	ECU per kg	as % of DMI
Ireland	40	0.39	1%	121%	93%
Finland	35	0.62	-14%	58%	88%
Denmark	28	0.84	19%	25%	81%
Sweden	27	0.79	-8%	32%	77%
Spain	22	0.52	27%	15%	91%
Germany	21	0.86	-7%	47%	88%
Austria	20	0.91	3%	31%	83%
European Union (15)	18	0.86	1%	33%	95%
Belgium and Luxembourg	18	0.95	2%	29%	55%
France	18	0.96	-11%	40%	86%
Greece	18	0.38	31%	-8%	89%
Netherlands	15	1.10	-5%	40%	53%
Italy	14	1.18	8%	23%	88%
UK	14	1.08	-2%	43%	81%
Portugal	13	0.51	5%	50%	89%

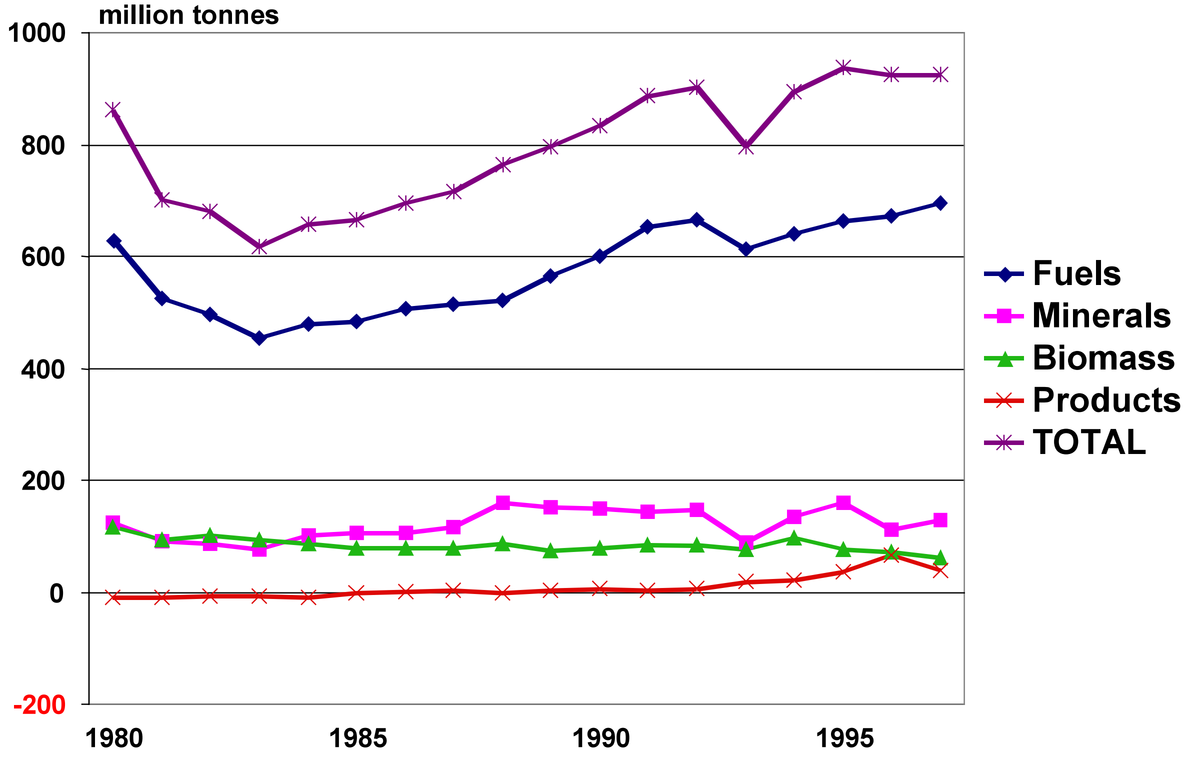
9. Physical Trade Balance

The *Physical Trade Balance (PTB)* measures the physical trade surplus or deficit of an economy. PTB equals imports minus exports. Physical trade balances may also be defined including hidden flows associated with imports and exports (e.g. on the basis of TMC accounts). In the present study only physical trade balances for commodities could be established.

From 1980 to 1997 the EU-15 was a net importer of commodities at 617 to 938 million tonnes (FIGURE 9.1). This was mainly due to fossil fuels (68% to 77% of PTB). In contrast to domestic extraction and domestic material consumption, minerals do not play a dominant role in foreign trade flows (11% to 21% of PTB). This is similar for biomass (7% to 15% of PTB).

The trend of PTB of commodities shows that the EU is continuously using more foreign resources than it is providing to other economies.

Figure 9.1: Physical trade balances (PTB) of commodities by material groups:
EU-15 1980-1997.



In general the 15 Member States showed a similar trend of PTB of commodities as the EU as a whole. From 1980 to 1997 only three countries temporarily had a negative PTB, i.e. these economies exported more commodities than they imported (TABLE 9.1). These were the UK in 1983, Greece in 1988, and Sweden in 1995 to 1997[24].

Table 9.1: Physical trade balances (PTB) of total commodities:
EU-15 and Member States, 1980-1997.

PTB commodities, '000 tonnes, 1980 - 1997.			
	Median	Minimum	Maximum
EUR 15	797213	616833	937987
Belgique/Belgie and Luxembourg	65217	49299	75965
Danmark	13501	6090	17283
Ellas	5708	-592	13326
Espana	65532	39868	85942
France	119945	95521	153372
Ireland	10683	7874	23846
Italia	170008	149893	192005
Nederland	57566	32389	109447
Portugal	19290	12374	29903
United Kingdom	16666	-3178	72219
Österreich	21220	16380	27250
Sverige	6155	-6440	17223
Suomi/Finland	19370	17073	24988
Deutschland	168092	149548	239974

[24] Thus, only 5 out of 270 data points (1.9%) were negative PTB commodities values.

A more detailed picture is obtained from the comparison of imports, exports and PTB per capita values, e.g. for the EU and Member States in 1997 (Table 9.2).

It should be noted that the absolute PTBs of EU Member States add up to EU-15 PTB, because the effect of intra-EU trade cancels out, whereas this is not true for imports and exports taken individually. Hence, the comparison between the EU-15 values of imports and exports with those of individual Member States given below is only indicative.

In 1997, the EU imports per capita at 3.5 t were at the lower end (3rd lowest) of the Member States' values. Belgium and Luxembourg imported most at 20.7 t/capita, followed by the Netherlands (17.3 t/capita) and Finland (10.2 t/capita). At the other end of the scale ranged Greece at 3.2 t/capita and the UK at 3.4 t/capita.

Belgium and Luxembourg also took the first position within the EU in exports per capita at 14.7 tonnes, closely followed by the Netherlands at 13.5 t/capita, indicating their relevance as major entry and exit points of foreign trade resources to and from the EU. The EU-15 exports at 1 t/capita were the lowest, next came Portugal (1.5 t/capita) and Italy (1.9 t/capita).

PTB of the EU at 2.5 tonnes per capita represented a medium value among the 15 Member States, where Belgium and Luxembourg were at top with 6 t/capita, and Sweden had the only negative PTB at -0.6 t/capita. Greece showed in general a low level of foreign resource exchange in terms of imports, exports and PTB.

The relation of PTB to imports indicates to which extent the foreign trade of an economy is biased towards foreign resources. In 1997, the EU-15 PTB was 70% of imports which represented the highest proportion, followed by Portugal at 67% and Italy at 57%. Only Sweden had provided more resources (8%) to other economies than it imported.

Table 9.2: Imports, Exports, and physical trade balance (PTB) of total commodities: EU-15 and Member States, 1997.

1997	Imports	Exports	PTB	
	tonnes per capita	tonnes per capita	tonnes per capita	% of imports
EUR 15	3.5	1.0	2.5	70%
Belgique/Belgie and Luxembourg	20.7	14.7	6.0	29%
Danmark	9.8	6.6	3.3	33%
Ellas	3.2	2.2	1.0	33%
Espana	4.1	2.1	2.0	49%
France	5.2	3.1	2.2	41%
Ireland	7.3	3.1	4.2	57%
Italia	5.0	1.9	3.1	62%
Nederland	17.3	13.5	3.8	22%
Portugal	4.5	1.5	3.0	67%
United Kingdom	3.4	3.2	0.2	7%
Österreich	7.3	3.9	3.4	46%
Sverige	7.4	8.0	-0.6	-8%
Suomi/Finland	10.2	6.8	3.5	34%
Deutschland	5.7	2.9	2.8	49%

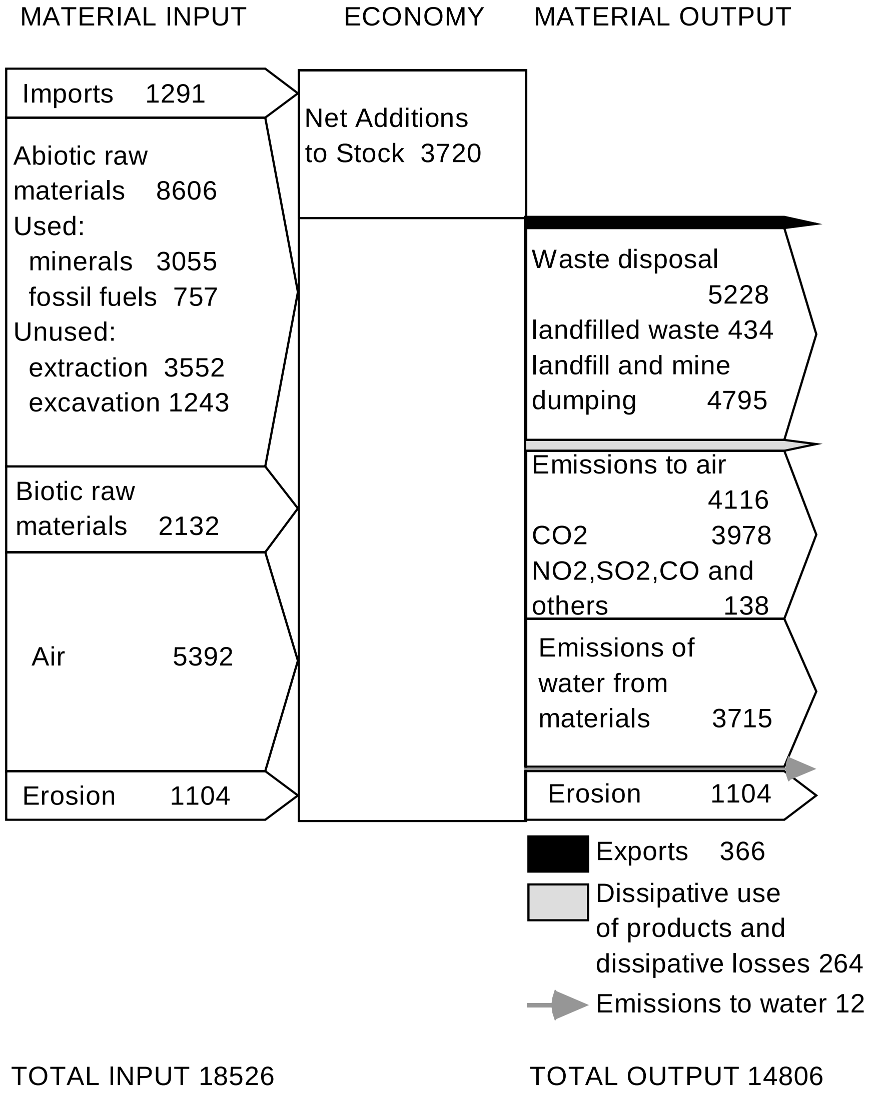
10. Material balances

10.1. The material balance

National physical accounts allow to organise flow data in an integrated framework to provide an overview on the metabolism of an economy. As an example, Figure 10.1 presents the material balance for the EU-15. The input side comprises imported materials, materials harvested or extracted from the domestic economy, and inputs of oxygen required for fossil fuel combustion and human and animal respiration. Materials retained in the economy are shown as net additions to stock. On the output side, the figure shows exported materials, outflows to land, air, and water. Domestic hidden flows are shown on both sides of the system. Because they do not enter the economy they are represented as a simultaneous input to, and output from the economic system.

The material flow balance shows the composition of the material throughput of an economy, its dependence on imports, the physical growth of its infrastructure, and the quantities of material released to the environment. The comprehensive balance allows setting priorities based on knowledge of the societal metabolism, and supports the derivation of indicators which track progress on the European or national level. The German Federal Statistical Office prepared a first national material flow balance in 1995 and, partly as a result, Germany became one of the first countries to establish national targets for improving the efficiency of materials use.

Figure 10.1: Material flow balance of EU-15, 1996, million tonnes



The material flow balance of EU-15 was compared with the account for Germany in 1996 (TABLE 10.1). The EU economy required 18.5 billion tonnes total inputs in 1996 which was 50 tonnes per capita[25]. Germany had a higher per capita input of 65 t/cap in 1996. The Net Additions to Stock (NAS) is very similar as share of total input (20% in EU, 18 % in Germany), as well as per capita (10 t/cap in EU, 11 t/cap in Germany).

Despite of the similar overall structure of the metabolism of EU and Germany there were remarkable differences in the composition of inputs and outputs. The share of non-renewable or abiotic raw materials from domestic extraction in Germany was significantly higher than in the EU as a whole (64% vs. 46%). This was mainly due to high amounts of overburden extraction for German lignite mining. As a consequence unused extraction accounts for 37% of total domestic inputs in Germany. Vice versa, the EU-15 economy was to a greater extent based on renewable materials from domestic harvest than Germany (12% vs. 4%). However, the higher volume of agricultural input also caused relatively higher shares of erosion (6% vs. 2%).

The huge material flows of German lignite mining further caused a high share of waste disposal (44%) in total domestic outputs as compared to EU-15 (28%). The higher share of oil and gas in energy consumption of the EU is reflected by higher proportions of emissions of water from materials (20%) than in Germany (12%). And CO_2 emissions contribute a slightly higher proportion to the outputs of the EU compared with Germany (21% and 19%), although the per capita level is slightly lower in the EU as a whole.

Materials productivity expressed as GDP per total inputs of the EU-15 was 15% higher than for Germany (0.31 ECU per kg vs. 0.27 ECU per kg). The difference in productivity was even higher when material outputs were the denominator (plus 22% in EU-15). Productivities with respect to net additions to stock were almost the same (plus 2% for EU-15).

The comparison between the material flow balances of EU-15 and Germany may be seen as an example to evaluate which of the two economies is more sustainable with respect to certain metabolic characteristics. Obviously, the domestic resource extraction in Germany is significantly less resource efficient and less based on a renewable or re-growing basis than in the EU as a whole, a fact which also results in a much higher share of waste disposal as landfill and mine dumping. Emissions of carbon dioxide and other air pollutants contribute a slightly higher share of material outputs to the environment EU-wide. Per capita levels indicate a similar contributions to global warming Eu-wide and in Germany but a much higher amount of emissions EU-wide that contribute to eutrophication and acidification. The annual growth of the technosphere, expressed as net additions to stock, proceeds with a similar rate in the EU and in Germany.

In order to compare the metabolic performance of economies, indicators such as TMR, DMI, DMC and the corresponding productivities should also be considered. The material flow balance provides a basis for the derivation of DMI and DMC as well as additional indicators such as TMO, DMO and NAS. The categorisation of the different input and output flows allows for instance insights into the share of re-growing resources. Also a functional differentiation is possible, distinguishing the flows and stock changes which are associated with e.g. energy supply, nutrition or housing (Bringezu 2000a). When provided in time series, the comprehensive flow balance allows to discover shifts of environment burden between different media, for instance, the increasing proportion of outflows to the atmosphere (see chapter 7).

[25] By chance the value is identical to the TMR. However, TMR comprises all domestic and foreign resource requirements without water and air, whereas the input of the material flow balance is restricted to the domestic territory and comprises air inputs (e.g. for combustion).

Table 10.1: Comparison of the material balance for EU-15 and Germany, 1996.

1996	million tonnes		% of total input		tonnes per capita		ECU per kg	
	EU-15	Germany	EU-15	Germany	EU-15	Germany	EU-15	Germany
Imports	1291	475	7%	9%	3	6		
Abiotic raw material	8606	3443	46%	64%	23	42		
Used: minerals	3055	898	16%	17%	8	11		
Used: energy carriers	757	253	4%	5%	2	3		
Unused extraction	3552	1996	19%	37%	10	24		
Excavation	1243	296	7%	6%	3	4		
Biotic raw materials	2132	225	12%	4%	6	3		
Air	5392	1080	29%	20%	14	13		
Erosion	1104	126	6%	2%	3	2		
TOTAL INPUT	18526	5348	100%	100%	50	65	0.31	0.27
Exports	366	228	2%	4%	1.0	2.8		
Waste disposal	5228	2329	28%	44%	14	28		
controlled waste disposal	434	119	2%	2%	1.2	1.5		
landfill and mine dumping	4795	2210	26%	41%	13	27		
Dissipative use of products and dissipative losses	264	47	1.4%	0.9%	0.7	0.6		
Emissions to air	4116	1005	22%	19%	11	12		
CO2	3978	990	21%	19%	11	12		
NO2,SO2,CO and others	138	15	0.7%	0.3%	0.4	0.2		
Emissions of water from materials	3715	639	20%	12%	10	8		
Emissions to water	12	37	0.1%	0.7%	0.03	0.45		
Erosion	1104	126	6%	2%	3	2		
TOTAL OUTPUT	14806	4411	80%	82%	40	54	0.39	0.32
Net Additions to Stock	3720	938	20%	18%	10	11	1.55	1.52

Besides the unsustainable volume and structure of the material throughput of industrial economies the physical growth and expansion constitutes a severe and continuously rising risk for the future.

10.2. Net Additions to Stock

Net Additions to Stock (NAS) measures the physical growth rate of an economy. New materials are added to the economy’s stock each year (gross additions) in buildings and other infrastructure, and materials incorporated into new durable goods such as cars, industrial machinery, and household appliances, while old materials are removed from stock as buildings are demolished, and durable goods disposed of. A sustainable economy would be characterised by zero NAS, i.e. a flow equilibrium between inputs and outputs of the material flow balance.

In previous studies it was found that the material flows added to stock each year were of comparable magnitude to DPO in Austria, Germany, Japan, and the UK – and they were around one-third to one-half of the size in the United States and the Netherlands (Matthews et al. 2000, Bringezu and Schütz 2001c). In per capita terms, Austria and Germany add the greatest amount to the material stock each year (11.5 metric tons per person) closely followed by the UK with 10.6 tonnes per capita in 1998. The United States appears to add the least amount, below 8 tonnes per person.

Additional information on the amount of the annual net additions to stock in EU-15 and its Member States was gained from the present study. The results prove that the technosphere in all these countries grows more or less linearly over time (FIGURE 10.2). The per capita accumulations of materials from 1990 to 1996 were highest for Sweden, Ireland, Finland and Denmark, and lowest for the USA, Greece, Italy, the Netherlands and Portugal. Similar per capita increases of NAS were recorded for the EU as a whole and for Japan, as well as for France and Belgium and Luxembourg.

In per capita terms Ireland, Sweden and Finland[26] had the highest amount of material added to stock in 1996 with 28 t/cap, 22 t/cap and 21 t/cap, respectively (TABLE 10.2), much higher than values reported so far for Germany and Austria. The EU as a whole added 10 t/cap. The lowest rate of increase was recorded for Italy at 7 t/cap. Changes from 1990 to 1996 on the per capita level of NAS ranged from plus 52% in Greece to minus 36% in Finland.

Figure 10.2: Cumulated Net Addition to Stock (NAS) per capita in EU-15 and international comparison, 1990-1996.

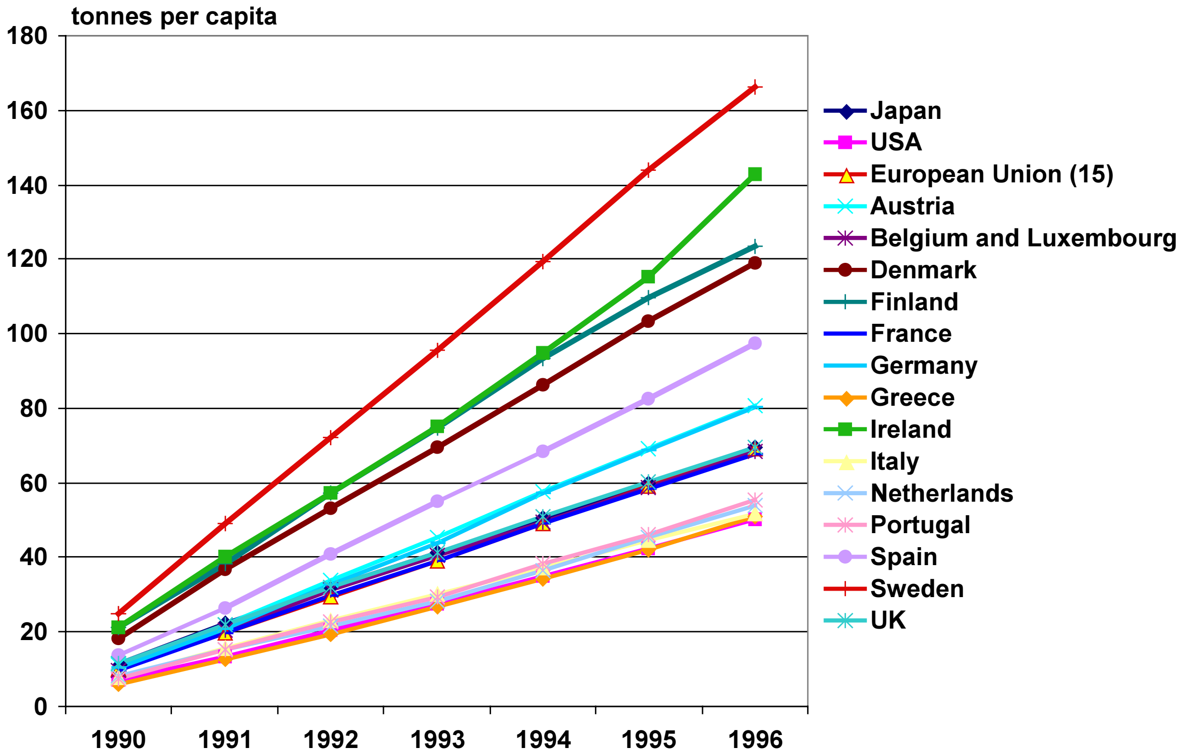


Table 10.2: Physical growth of the economy: Net addition to stock (NAS) per capita 1996, changes 1990 to 1996 in %, EU-15 and Member States.

NAS	t per capita 1996	Change of growth rate from 1990 to 1996 t per capita
Ireland	28	30%
Sweden	22	-11%
Finland	21	-36%
Denmark	15	-16%
Spain	15	9%
Germany	12	5%
Austria	12	3%
European Union (15)	10	-1%
Belgium and Luxembourg	10	-2%
Portugal	9	22%
France	9	-7%
UK	9	-21%
Greece	9	52%
Netherlands	9	5%
Italy	7	-9%

[26] The Finnish NAS includes storage of waste which was about 15.7% or 3.3 tonnes per capita in 1997 (Muukkonen 2000).

11. Conclusions and recommendations

Economy-wide material flow accounting provides an overview of the physical basis of the economy and its relation to major environmental pressures. Aggregated indicators on the metabolic performance of the economy can be derived.

It seems important to note that the accounting allows the monitoring of progress towards the objectives of the 6th Environment Action Programme of the European Commission:

Tackling climate change: MFA proves that CO_2 emissions constitute a major component of the economic metabolism. The effect of mitigation measures can be monitored directly. Material flow balances allow the comparison of emissions to the atmosphere with other releases to the environment, and thus indicate a shift of environmental burden (composition of TDO). For instance, the atmosphere is increasingly being used for global waste deposit.
Protect Nature and Wildlife: MFA documents the continuously high volume of non-renewable resource extraction which often devastates natural habitats. It also monitors the release of dissipative outputs such as fertilizers and pollutants which also burden natural ecosystems. Most importantly, MFA reveals the physical increase of the technosphere which leads to a steady destruction of productive and natural land (NAS).
Address environment and health issues: Living in a healthy environment demands a reduction of the unsustainable resource requirements, the protection of landscapes and a reduction of pollutants. Thus, MFA contributes significant aspects also to that issue (TMR, DMI, TDO).
Preserve natural resources and managing waste: MFA monitors the use of natural resources and the resulting waste and emissions comprehensively. MFA comprises all material flows from resource extraction to final disposal. Waste and emissions prevention may be indicated by a reduction of resource requirements (TMR, DMI). MFA is the pre-requisite to document progress towards resource efficiency and to support policy with key indicators based on a systems perspective (GDP/TMR, GDP/DMI). It provides a basis for specifying the resource efficiency of the different economic sectors. MFA also allows to differentiate the volume and structure of resource requirements of production and consumption (TMR, DMI vs. TMC, DMC).

With respect to future activities to improve the MFA related information basis for the priority fields mentioned above, we recommend the Commission and in particular Eurostat to

- support the national statistical offices of the Member States and the accession countries with the implementation of the Methodological Guide and the capacity building for regular MFA activities. To this end, for instance, seminars may be helpful.
- develop a framework and gradually establish a reference database for European and national MFA containing technical coefficients and hidden flows coefficients, as proposed by the MFA Task Force. The technical coefficients may be used by national statistical offices and thus foster a harmonized accounting. The provision of coefficients on hidden flows may begin with the domestic flows. An "initial set" could be assembled based on available data. Additional data from new national studies should be used for updating and extending the data set. In effect, the database will support national statistical offices as well as Eurostat and the EEA in order to provide regular MFA based accounts and indicators, e.g. on resource efficiency.
- build up an EU database on resource requirements of especially important commodities in a modular way. For instance, there is already a significant increase of electricity trade. This non-physical commodity is linked with major resource requirements. Leaving these implications out of consideration (e.g. DMI and DMC do not cover that issue) may distort the evaluation of the resource efficiency of economies. A data module on the resource intensity

of the electricity produced in the Member States and in those countries from which the EU imports electricity would solve this problem.

- proceed with the analysis of the currently existing MFA information. For instance, the driving forces of the significant trend of decoupling resource requirements and economic growth should be analysed in order to support policies for enhancing this tendency.
- further analyse the sectoral contributions to direct and indirect material flows. The performance of the different sectors with regard to resource efficiency and its development should be monitored and studied with regard to major material flows and the relation to GDP and employment.
- investigate the consequences of accession in terms of resource requirements and efficiency. First data on Poland indicate that resource efficiency may increase but absolute resource requirements will rise in the course of the accession. Furthermore, a regional differentiation of the EU material flows (e.g. northern and southern Member States) may indicate the degree of coherence with respect to metabolic performance.
- study the flow of selected materials critical for the resource requirements of the EU. For instance, the import of precious minerals significantly contributes to the TMR of the EU. However, the data basis deserves improvement and the environmental impacts of those flows require attention.
- further analyse the physical growth of the EU economy. The expansion of the technosphere imposes severe long-lasting and increasing pressure to the environment. Better information is required on the absolute volume as well as composition of the stock. The physical growth rate should be analysed for trends which may lead to a decoupling from economic growth.

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Annex: Accounting model and data system

The following section described the basics and details of the accounting of material balances of the EU-15 in time series. In the first chapter „Data sources available and feasibility evaluation“, data sources available for the study are described and the feasibility of the overall accounting for EU-15 is evaluated. The second chapter „Accounting for material balances of EU-15“ describes in detail how the accounting model and data system for material balances of the EU was set up based on data available and additional estimates.

A.1. Data sources available

The aim of the second part of the study was to compile data series for EU-15 1980 to 1998 covering the material balance framework worked out during part one of the study. For this purpose the following steps had to be taken:

- Integration, as far as possible after revision, of existing national material flow databases available for Austria, Denmark, Finland, France, Italy, the Netherlands, Sweden, the United Kingdom, and Germany,
- use of the EU database compiled by the Wuppertal Institute in the course of recent material flow studies especially for the European Environment Agency (EEA 2000, Bringezu and Schütz 2001a,b), and
- for the other Member States and eventually missing data of the existing Member States‘ databases, data published by Eurostat, DG III, OECD, IEA, FAO and others with direct relevance for material balances were collected and analysed.

The use of existing databases of Member States for the EU material balance was restricted to domestic material inputs, outputs and net additions to stocks which can be sumed up to the EU total. Foreign trade data for single Member States comprise intraregional and extraregional EU trade whereas data for the EU as a whole comprise by definition the extraregional EU trade only. Consequently, material flows associated with imports and exports are presented as EU totals and are not attributed to individual Member States. The compilation of this EU foreign trade databases is based on the Eurostat data on CD-Roms covering the period 1976 to 1997. This, however, means that aggregated EC/EU foreign trade data have an underlying changing regional coverage reflecting the development by accession of new Member States like Austria, Finland and Sweden in 1995. Furthermore, the Extra-EU trade of these countries is not available in the Eurostat source. It could be, of course, obtained by detailed data extractions from the individual national statistics. However, the latter was not feasible within the scope of this study (it could be a future activity between Eurostat and the respective national statistical offices). Therefore, in order to establish a consistent time series for EU-15, a practicle solution had to be found for additional estimates of the Extra-EC/EU foreign trade by countries which were not yet Member States in the study year. This will be described in chapter A.2.4.

Existing national material flow databases are listed in Table A.1. These showed very diverting usefulness for the envisaged EU material balance in time series, as indicated by the data availability for main material groups. The most advanced data sets in this respect are those for Austria, Finland, Germany, the Netherlands and the UK which fit completely to the EU framework. No original databases were found for Belgium, Greece, Ireland, Luxembourg, Portugal and Spain. Currently, work is done in Portugal on direct material inputs (Paulo Ferrão, Instituto Superior Técnico, Lisboa, personal communication).

Comprehensive material flow data for the 15 EU Member States were available for domestic used and unused extraction 1985 to 1997 in the aforementioned database of the Wuppertal Institute established mainly during the EEA study on Total Material Requirement of EU-15. However, this database did not include material outputs. Data for emissions and waste, dissipative outflows and net additions to stocks were available as indicated in Table A.1.

Domestic used and unused extraction data for the 15 Member States of the EU were at least available for 1985 to 1997. Data for material outputs to the environment were more critical, this situation will be described in the following. Altogether, it turned out that a reasonable data coverage including estimates to derive a comprehensive material balance was given for 1990 to 1996. No further efforts were made to collect individual material output flows data prior or after this period.

In more detail the data availability in the Member States for the EU material balance is summarised in TABLE A.2 and illustrated in Figures A.1 to A.19 for material sub-categories. Figure A.20 presents a summary of available material categories in such a way that each material or material group available in a year in a Member States gets 1 point. The maximum score for complete (yet unweighted) data coverage for a Member State in one year is 17 and for the whole EU-15 it is 255. Complete data coverage is only given for Germany over the entire period 1980 to 1998 and for Austria in 1995. For the EU-15 resulting from the individual scores of its Member States 1990, 1992 and 1994 are the years with most complete data coverage on material outputs to the environment. However, for some countries other years provide a better database; e.g. for Denmark it is 1993.

Table A.1: National material flow databases

Member State	Data source	Period	Data availability				
			Domestic raw materials extraction	Unused domestic materials extraction	Emissions to air and water, and waste landfilled	Dissipative use of products and dissipative losses	Net additions to stock
AUSTRIA	IFF	1975-96	X	X	X	X	X
	Eurostat	1960-97	X				
DENMARK	Danmarks Statistik	1990 (1)	(X) (2)		(X) (3)		X
FINLAND	Juutinen and Mäenpää	1970-99	X	X			
	Eurostat	1980-97 (4)	X	X	X	X	X
FRANCE	Chabannes	1975-94	X	X			
GERMANY	Federal Statistical Office	1960,70,80, 90 (5); 1991-98 (6)	X	X	X	X	X
	Wuppertal Institute (WI)	1975-96 (7)	X	X	X	X	X
ITALY	Eurostat	1988	X				
	De Marco et al.	1975, 1994 (8)	X	X	X		X
NETHER-LANDS	Kleijn and van der Voet	1975-96	X	X	X	X	X
SWEDEN	Eurostat	1987-97	X		X (9)		
UK	DETR/ONS/WI	1970-99 (10)	X	X	X	X	X

X: available without restrictions, (X): available with some limitation
1: air emissions available for 1990-92, 2: biomass input not available, 3: waste landfilled and emissions to water not available, 4: emissions and wastes, dissipative use of products and, thus, net additions to stock only for 1987, 1992 and 1997, 5: data for former West-Germany, air emission data also annually for 1970-90 from Federal Environment Agency, 6: data for re-united Germany (incl. former GDR), 7: 1975-90 former West-Germany, 1991-96 re-united Germany, 8: 1975 only domestic raw materials, 9: 1993 only, 10: database developed by WI with DETR and ONS.

Data sources referred to in Table A.1:

- IFF: Institute for interdisciplinary research and continuing education, Vienna; database published in Matthews et al. 2000, for material inputs also Schandl, H. (1998)
- Eurostat Working Papers 2/2000/B/6 - Gerhold, S. and Petrovic, B. (2000)
- Danmarks Statistiks: Pedersen, O.G. (1999), Physical Input-Output Tables for Denmark
- Juutinen, A. and Mäenpää, I. (1999). Time Series for the Total Material Requirement of Finnish Economy - Summary. Eco-efficient Finland project, Interim report 15 August 1999. University of Oulu, Thule Institute. http://thule.oulu.fi/ecoef; and personal communication by Ilmo Mäenpää.
- Eurostat Working Papers 2/2000/B/1 - Muukkonen, J. (2000)
- Chabannes, G. (1998). Material Flows Analysis for France, unpublished manuscript.
- Federal Statistical Office of Germany – Statistisches Bundesamt (1995, 1997, 1999): *Integrated Environmental and Economic Accounting – Material and Energy Flow Accounts*. Fachserie 19, Reihe 5. Wiesbaden
- Wuppertal Institute (WI), Germany, database published in Matthews et al. 2000
- Eurostat for Italy: Eurostat Working Papers 2/2000/B/8 - Femia, A. (2000)
- De Marco et al.: Material Flow Analysis of the Italian Economy, unpublished manuscript; also De Marco and Lagioia: Material throughput in the Italian Economy, unpublished manuscript
- Kleijn and van der Voet: Centre of Environmental Studies (CML) at Leiden University, The Netherlands, database published in Matthews et al. 2000
- Eurostat Working Papers 2/2000/B/2 - Isacsson, A., Jonsson, K., Linder, I., Palm, V. and Wadeskog, A. (2000)
- DETR/ONS/WI: Department of Environment, Transport and the Regions of the United Kingdom, Office for National Statistics of the UK, Wuppertal Institute: Total Material Resource Flows of the United Kingdom, Final Report to Contract Ref. No. EPG 1/8/62, Wuppertal Institute, 2001.

Figure A.21 provides information on which material categories data in Member States are missing in 1990 and in which other year(s) they are available or if they are not available at all. Most critical, especially for a complete time series of material outputs to the environment, was the data availability for landfilled waste which in most countries is only available for single years or even available only for municipal or industrial waste (see also Figure A.13). It was a special task in this study to find out waste coefficients to estimate missing data. This will be described in chapter A.2.5.3.

The data availability for other material categories than waste in Figure A.21 is largely very poor. However, from the experience gained so far by the national material flow studies for Austria, Germany, the Netherlands, the UK and Finland, it can be assumed that these data gaps will most probably not have a big influence on the quantitative overall result of the total material output to the environment.

Emissions to air data coverage was sufficient to derive reasonably comprehensive time series for 1990 to 1997. No further efforts were made to close data gaps prior to 1990. For example, it could not be assumed that missing data for HFC, PFC and SF_6 could be obtained by any way. However, in view of the very small quantities of these emissions as compared to CO_2 and other air emissions this does not influence the availability of the aggregated material flow indicators.

Concerning agricultural material categories as dissipative outputs, these were largely available in or derivable from agricultural statistics (FAOSTAT). No further efforts were made to estimate other dissipative outputs where national databasis were not available. This concerns mainly the data availability of emissions to water, thawing and grit materials, and dissipative losses.

In more detail, the data availability for individual categories of material outputs to the environment by the 15 Member States from 1980 to 1998 can be described as follows:

Emissions to air: for a data set with respect to full coverage of outputs completely balancing the inputs the following emissions should be included (following IPCC guidelines as expressed by EEA Technical Report No 41, EEA 2000a, and by EEA Technical Report No 52, EEA 2000b, except for emissions from respiration):

1. emissions from fuel combustion incl. international bunker fuels (emissions from biomass may be shown as memorandum item)
2. emissions from waste incineration

3. emissions from non-energetic industrial processes (only in case of net emissions)
4. emissions from solvent and other product use
5. emissions from agriculture
6. emissions from respiration of humans and livestock (only relevant for CO_2 and water vapor, and CH_4 from enteric fermentation)

CO_2 emissions from fuel combustion incl. international bunker fuels (1) and from waste incineration (2) are guaranteed by the EEA dataset from 1990 to 1998. They are further covered by the datasets of Austria, Germany and the Netherlands from 1980 to 1998. For the remaining 12 Member States from 1980 to 1989 available data from Eurostat only refer to emissions from fossil fuel combustion for energy purposes (potentially incl. international bunker fuels but not shown as separate item) but excl. incineration of waste. CO_2 emissions from non-energy sources (3-5, agriculture has no relevance here) are represented in the EEA database and in the country data sets of Austria, Germany and the Netherlands, but not in the Eurostat database prior to 1990. Data for CO_2 emissions from respiration of humans and livestock (6) are not readily available but can easily be estimated based on published coefficients and population and livestock numbers.

Like for CO_2 the EEA data provide emissions of **CH_4 and N_2O** for 1990-1998, **NOx, CO, NMVOC** and **SO_2** for 1980-1998, i.e. related to activities 1 to 5 before, as well as data on emissions of HFCs, PFCs and SF_6 but the latter are incomplete and do not allow to derive EU-15 totals (see Figure A.4). **NH_3** emissions are available for 1985 to 1997 with full coverage.

Prior to 1990 Eurostat data report emissions of **SO_2**, **NOx, CO, VOC** (**CH_4** plus **NMVOC**) and **PM** (particulate matter) based on data provided by Member States and OECD, but not **N_2O** emissions. In addition to EEA the CORINAIR 1990 inventory reports on **NH_3** emissions which, however, are characterised as probably incomplete and unreliable. Eurostat describes its two basic datasets, Member States/OECD and CORINAIR, as largely compatible with only minor differences. This would mean that in general emissions from activities 1 to 5 described before are represented and the database prior to 1990 is as complete as the EEA data set.

Emissions of **water vapor** from the combustion of energy carriers and from respiration are up to now not represented in common emission inventories. These emissions have for the first time been estimated for the physical input-output table for Germany 1990 (Stahmer et al. 1998). The basic emission coefficients for this estimation are available and were applied for this study.

Emissions to water (e.g. materials in waste water, dumping of sewage at sea) are not likely to play an important role with respect to the overall quantity of material outputs[27]. There seemed to be no chance to obtain missing data by estimates.

The critical data situation for **landfilled waste** has already been described. An estimation procedure to derive waste data on a very crude basis will be described in chapter A.2.5.3).

The data coverage for dissipative use of products in agriculture was in general very good (FAOSTAT), significant data gaps occurred for pesticides and other materials like compost and sewage sludge. Empirically, these are no major flows in quantitative terms.

Feasibility of obtaining or estimating missing data on **thawing and grit materials** and on **dissipative losses** seemed rather low and was not further followed in this study.

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[27] This may not be true if dredging is dumped into water. However, this information is not available in every Member State. Dredging in this study was attributed to disposal of unused extraction on the output side.

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TABLE A.2: Data availability for material outputs in Member States.

Member State	Emissions to air												Emissions to water				Waste landfilled				Dissipative use of products and losses					
	Greenhouse gases				Other gases and substances																Use of products					Losses
	CO2	CH4	N2O	HFC,PFC,SF6	SO2	NOx	VOC	NMVOC	CO	NH3	PM, Dust	Heavy metals	Organic C	N	P	Other	All wastes	Household waste	Industrial waste	Other waste	Mineral fertiliser	Organic manure	Pesticides	Other agricultural	Thawing, grit mat.	Roads, tyres
A	75-98	75-98	75-98	95, 98	75-98	75-98	75-98	75-98	75-98	75-97	75-96		75-96	75-96	75-96	75-96	75-96				75-98	75-98	75-96	75-97	75-96	75-96
B	85-98	90-98	90-98	90, 95-98	80-98	80-98	90-98	80-98	80, 85-98	80, 85-97	80, 90, 94							94			80-98	80-98	80, 85-97	90-97		
DK	83-98	89, 90-98	90-98	90-98	80-98	80-98	80, 85, 87-98	80-98	80-98	80-97								93			80-98	80-98	85-97	90-97		
D	75-98	75-98	75-98	75-98	75-98	75-98	75-98	75-98	75-98	75-98	75-98			75-98	75-98	75-98	75-98	75-98	75-98	75-98	75-98	75-98	75-98	75-98	75-98	75-98
EL	83-98	90-98	90-98	90-98	80-98	80-98	80, 85, 90-98	80-98	80, 85-98	80, 85-97								92		90	80-98	80-98	80, 86-89, 94-96	90-97		
E	83-98	90-98	90-98	90-98	80-98	80-98	80, 85-98	80-98	80, 85-98	80, 85-97						90		92		90	80-98	80-98	87-96	90-97		
F	83-98	90-98	90-98	90-98	80-98	80-98	85, 90-98	80-98	80-98	80, 85-97	80, 90-94							92			80-98	80-98	80, 85-97	90-97		
IRL	83-98	80, 89, 90-98	90-98		80-98	80-98	80, 85, 87-88, 90-98	80-98	80, 85-98	80, 85-97	80, 85, 90							84			80-98	80-98	80, 90-97	90-97		

TABLE A.2: cont.

Member State	Emissions to air												Emissions to water				Waste landfilled				Dissipative use of products and losses					
	Greenhouse gases				Other gases and substances																Use of products					Losses
	CO2	CH4	N2O	HFC,PFC,SF6	SO2	NOx	VOC	NMVOC	CO	NH3	PM, Dust	Heavy metals	Organic C	N	P	Other	All wastes	Household waste	Industrial waste	Other waste	Mineral fertiliser	Organic manure	Pesticides	Other agricultul	Thawing, grit mat.	Roads, tyres
I	83-98	85-89, 90-98	90-98	90-98	80-98	80-98	85-98	80-98	80-98	80-97	80, 85, 90						94	91		90	80-98	80-98	80, 85-97	90-97		
L	83-98	89, 90-98	90-98		80-98	80-98	80, 85, 90-98	80-98	80, 85-98	80, 85-97	85							93			80-98	80-98	91, 94-97	90-97		
NL	75-98	90-98	90-98	90-98	75-98	75-98	90-98	75-98	75-98	80-97	75-96			75-96	75-96	75-96	75-96				75-98	75-98	75-96	75-97		
P	83-98	90-98	90-98	95	80-98	80-98	80, 83, 85-98	80-98	80, 85-98	80, 85-97	80							92			80-98	80-98	91-96	90-97		
FIN	83-98	90-98	90-98	90, 94-98	80-98	80-98	80, 85, 87-88, 90-98	80-98	80, 85-98	80, 85-97	85-94, 97	87, 92, 97				87, 92, 97	87, 92, 97	87, 90, 92, 97	87, 92, 97	87, 92, 97	80-98	80-98	80, 85-97	87, 90-97		
S	83-98	90-98	90-98	94-95, 97-98	80-98	80-98	80, 88, 90-98	80-98	80, 85-98	80, 85-97	90							90	93		80-98	80-98	80, 85-96	90-97		
UK	83-98	80-89, 90-98	90-98	90-98	80-98	80-98	80, 83, 85, 87-98	80-98	80-98	80, 85-97	80-98					85, 90-98	97-98	89, 97-98	97-98	90, 97-98	80-98	80-98	88, 90, 92-97	90-97		

Data sources: as indicated in Table A.1 and: Eurostat: Statistical Yearbooks, Environment Statistics 1996; EEA: Annual European Community Greenhouse Gas Inventory 1990-1998, Technical Report No 41, Annual European Community CLRTAP emission inventory 1980-1998, Technical Report No 52; FAOSTAT: http://apps.fao.org

CONTENTS

Figure A.1: Data available for EU-15 Member States: CO_2 emissions

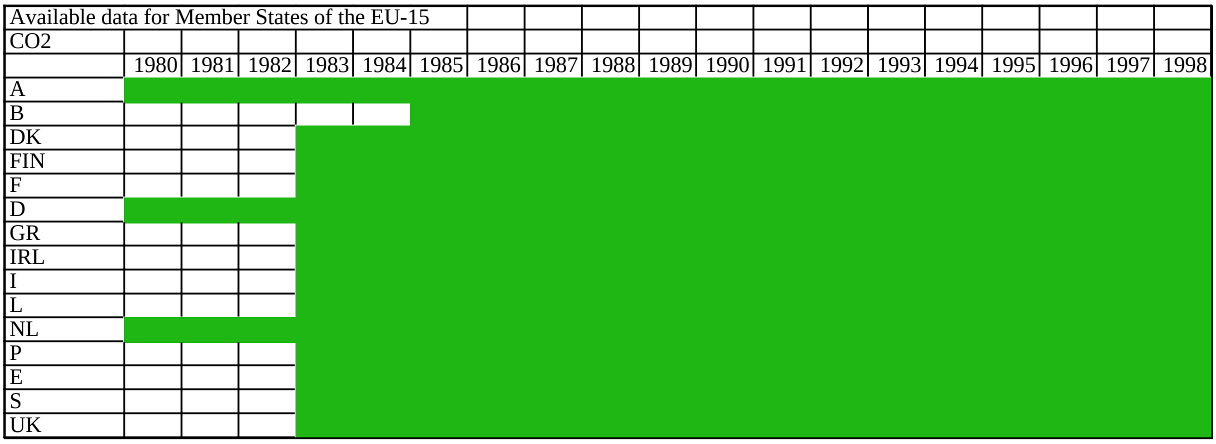


Figure A.2: Data available for EU-15 Member States: CH_4 emissions

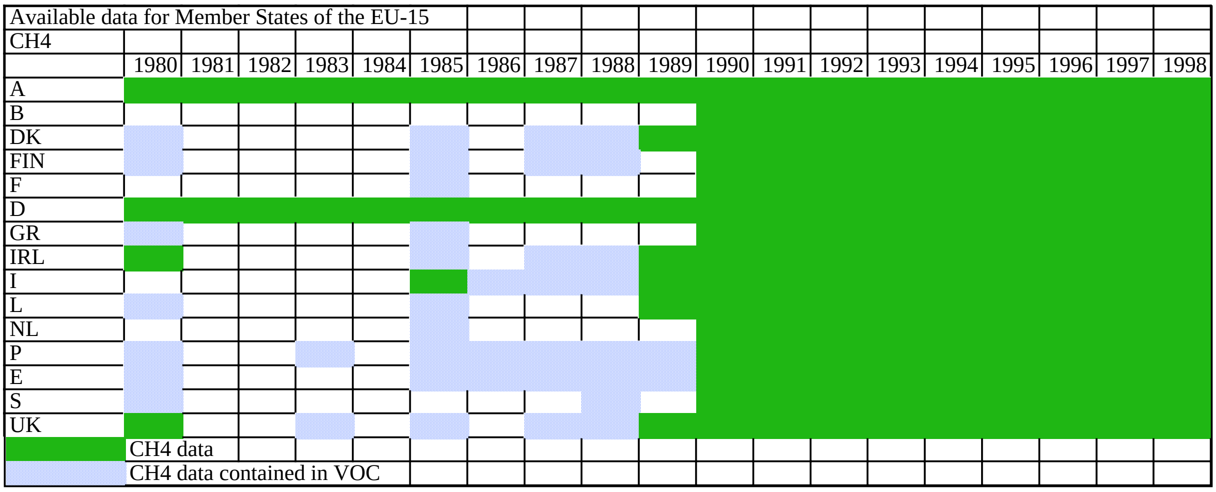


Figure A.3: Data available for EU-15 Member States: N_2O emissions

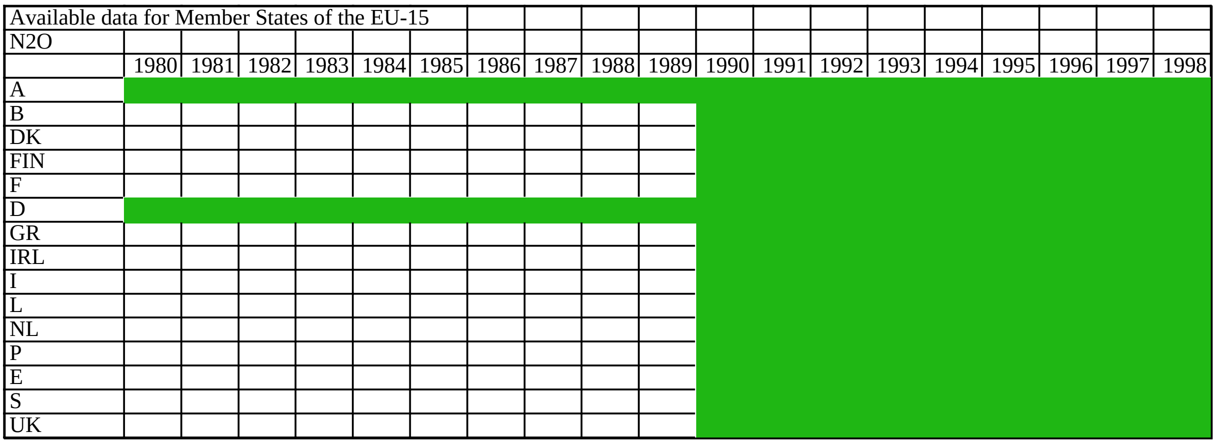


Figure A.4: Data available for EU-15 Member States: HFC, PFC, SF_6 emissions

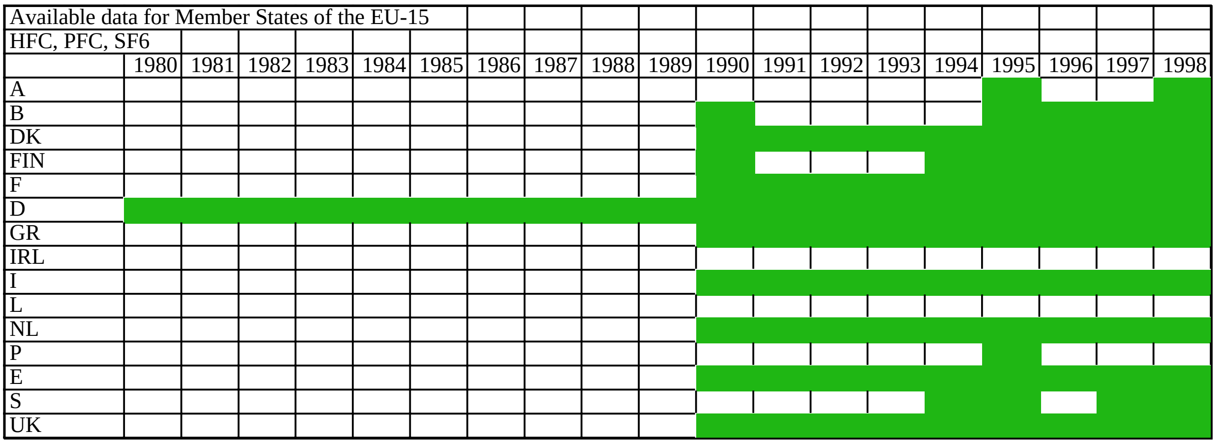


Figure A.5: Data available for EU-15 Member States: SO_2 emissions

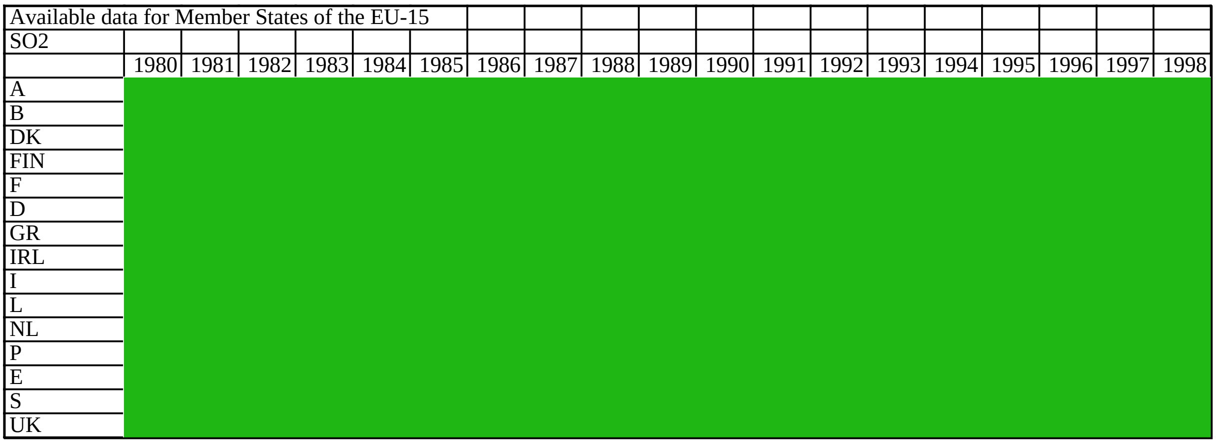


Figure A.6: Data available for EU-15 Member States: NO_2 emissions

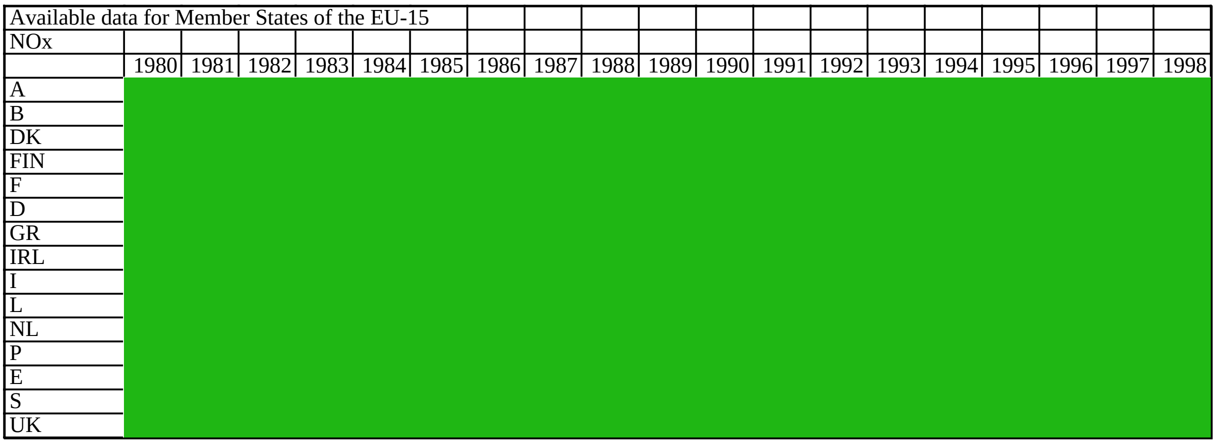


Figure A.7: Data available for EU-15 Member States: VOC emissions

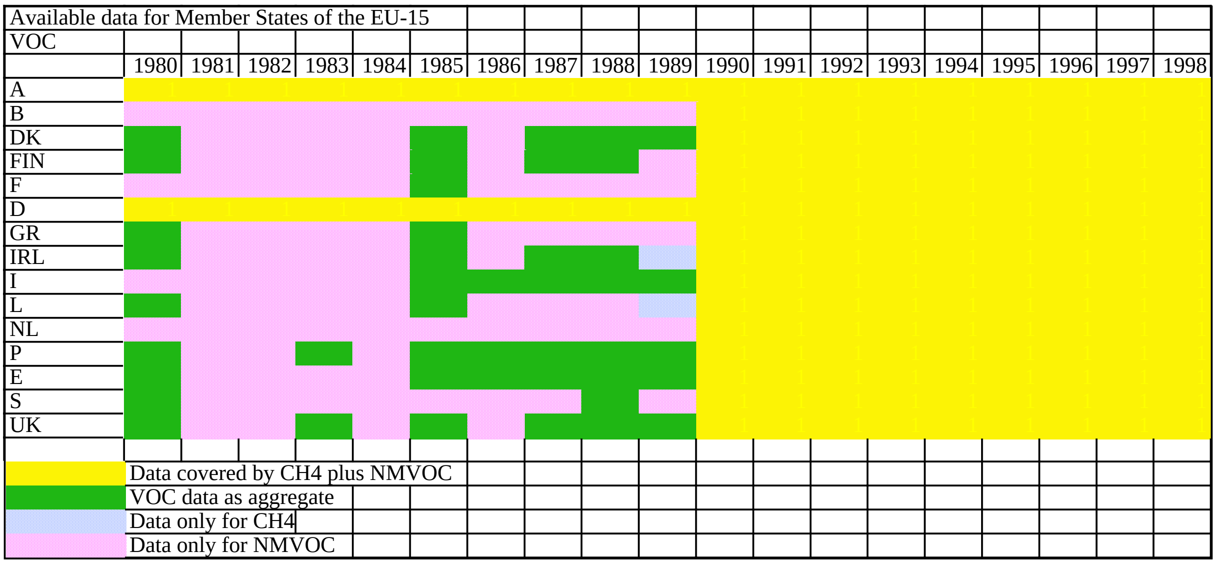


Figure A.8: Data available for EU-15 Member States: NMVOC emissions

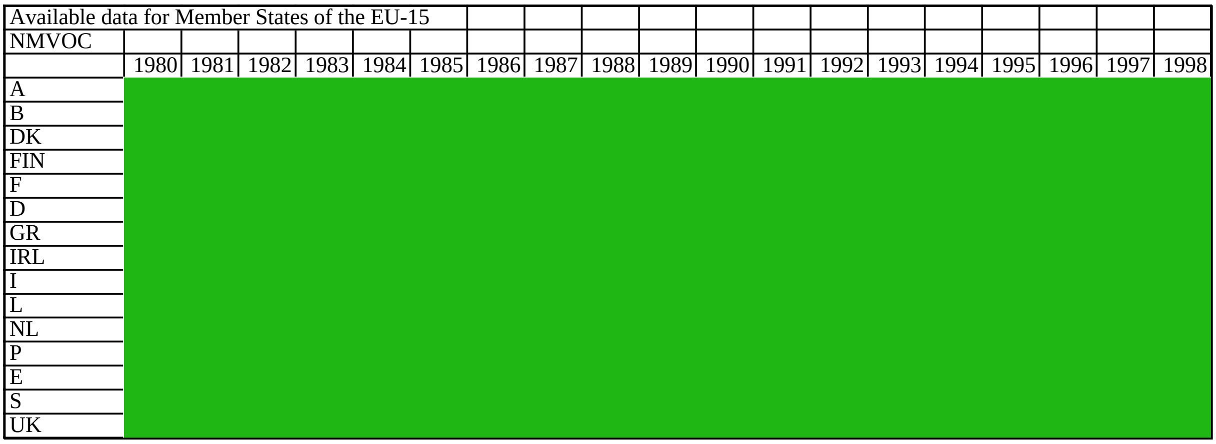


Figure A.9: Data available for EU-15 Member States: CO emissions

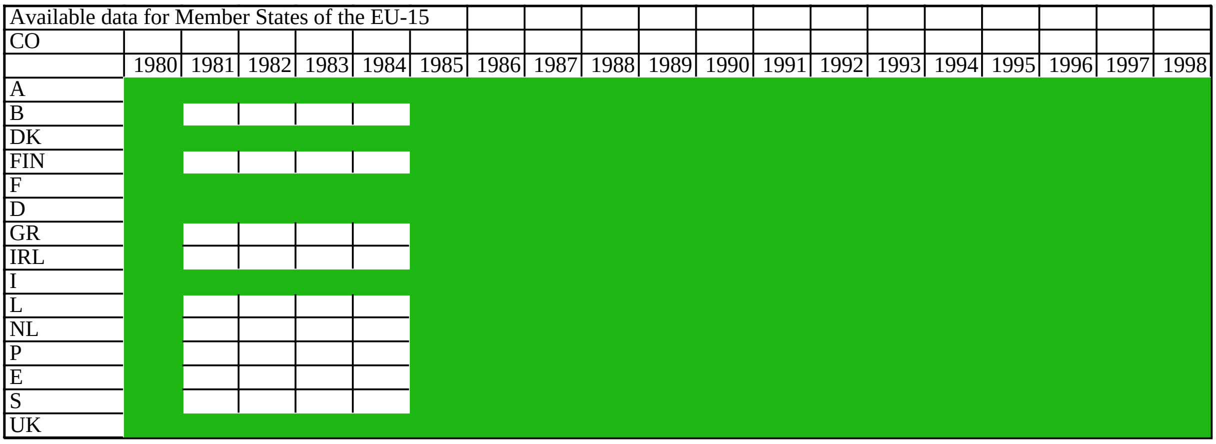


Figure A.10: Data available for EU-15 Member States: NH_3 emissions

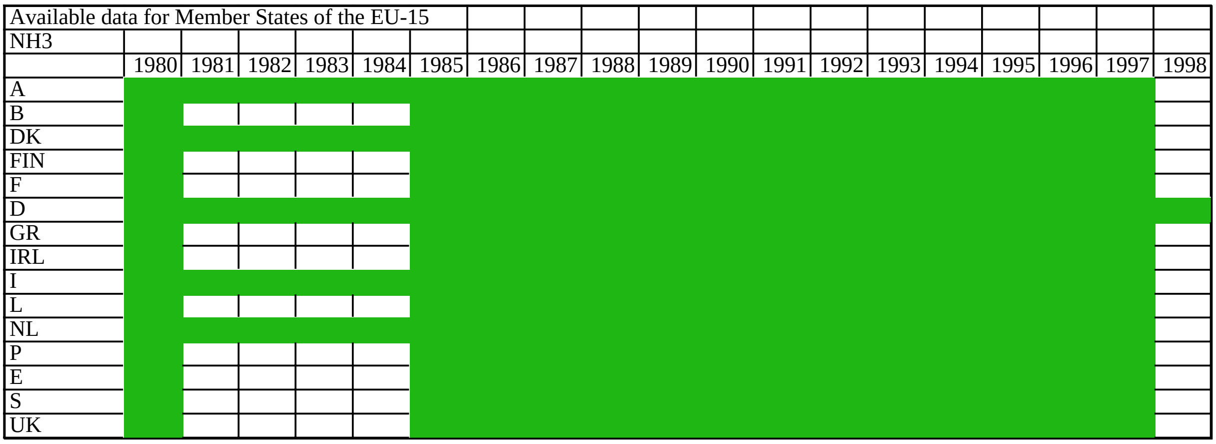


Figure A.11: Data available for EU-15 Member States: PM_{10},Dust emissions

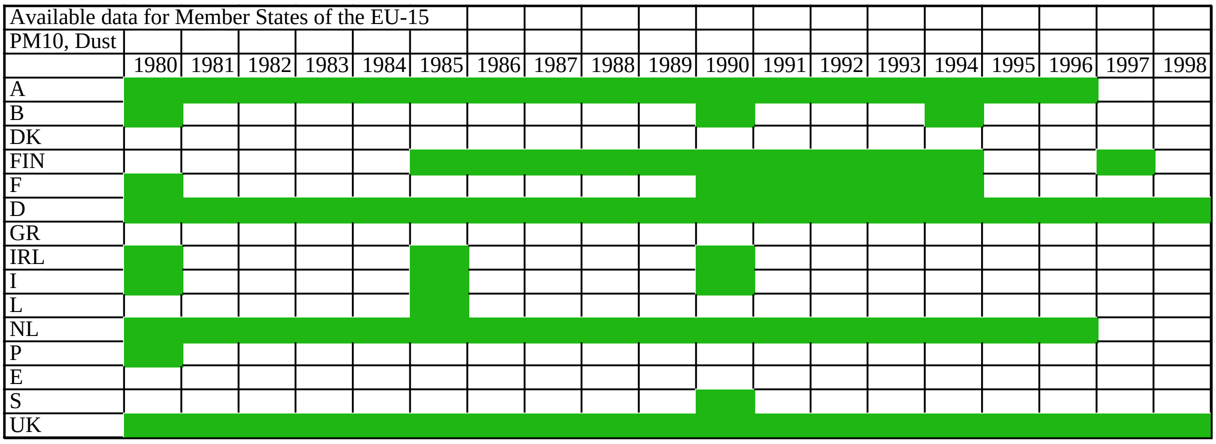


Figure A.12: Data available for EU-15 Member States: emissions to water

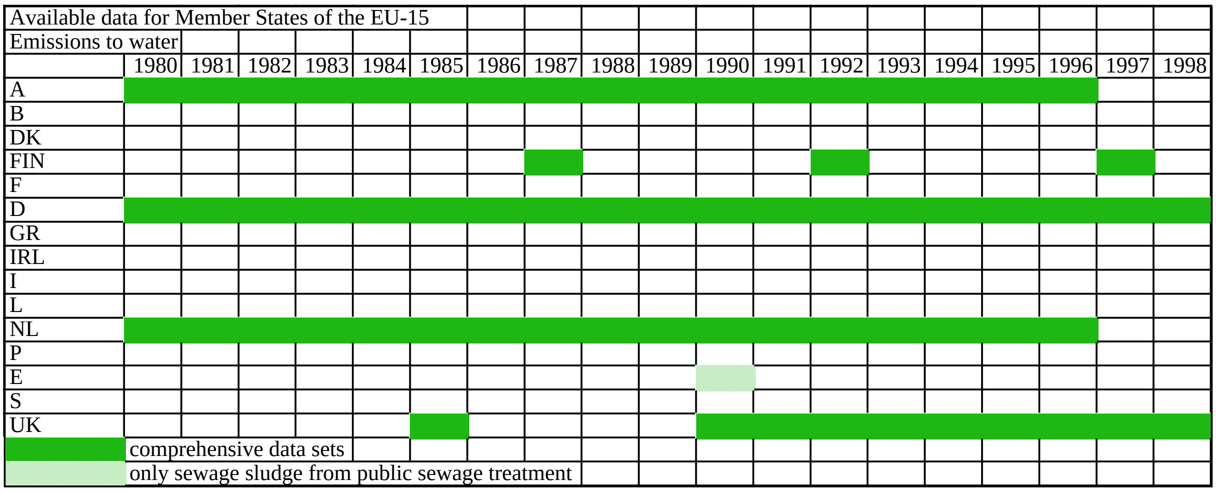


Figure A.13: Data available for EU-15 Member States: waste landfilled

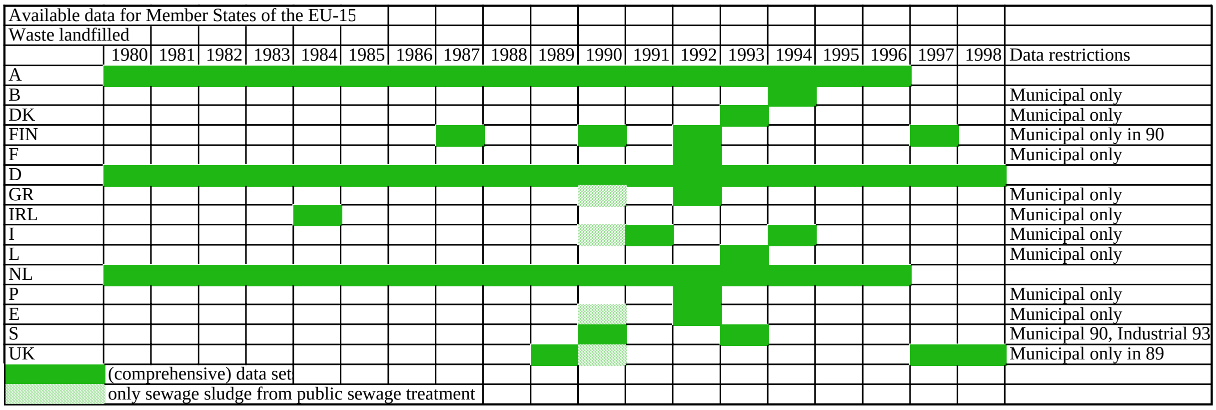


Figure A.14: Data available for EU-15 Member States: mineral fertiliser

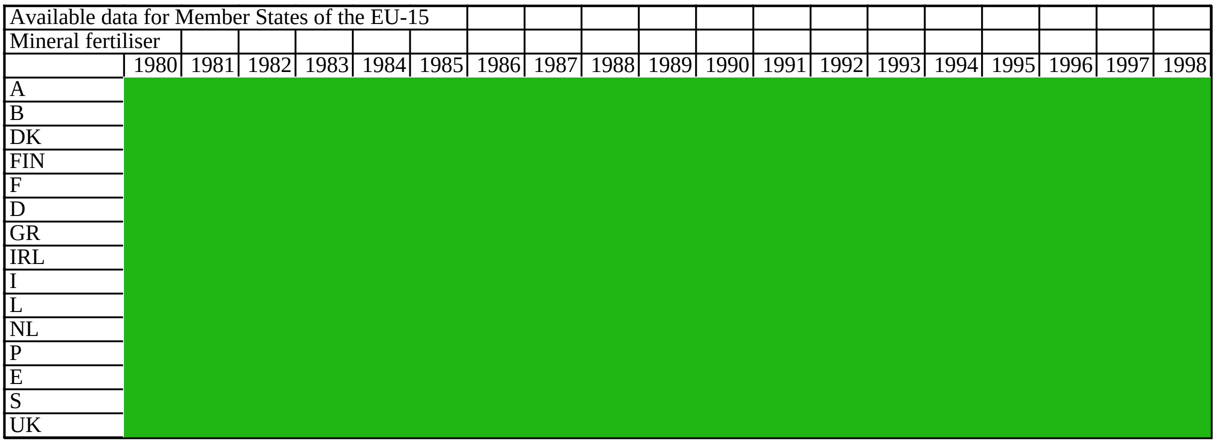


Figure A.15: Data available for EU-15 Member States: manure

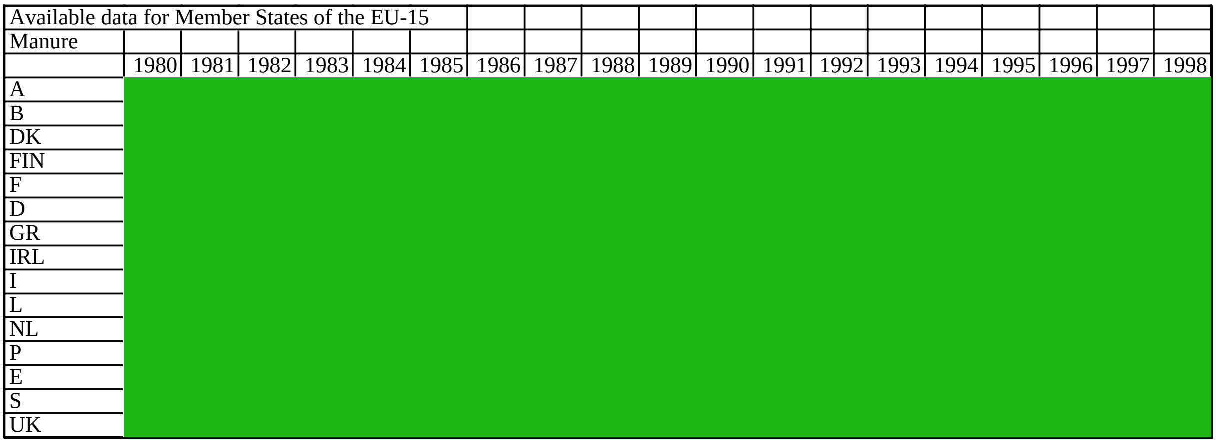


Figure A.16: Data available for EU-15 Member States: pesticides

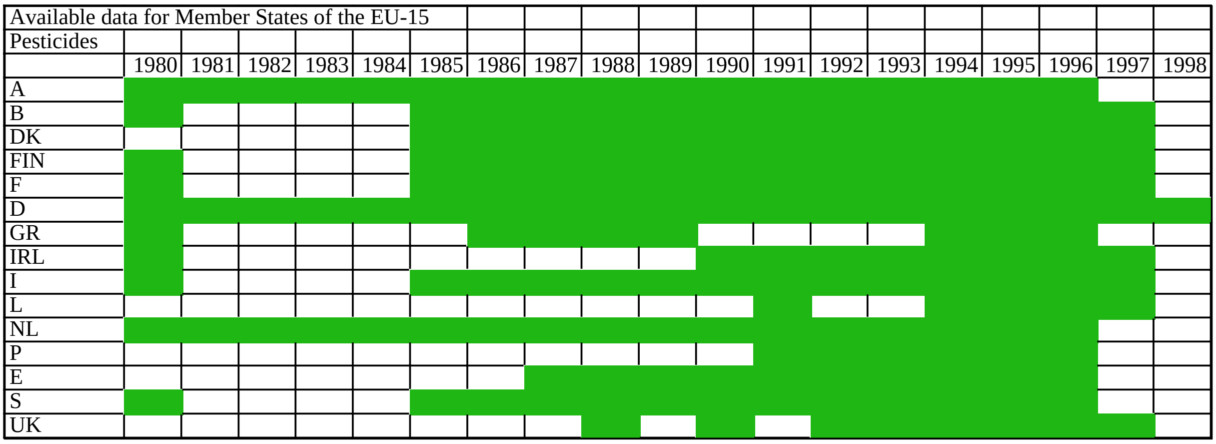


Figure A.17: Data available for EU-15 Member States: other agricultural dissipative outputs

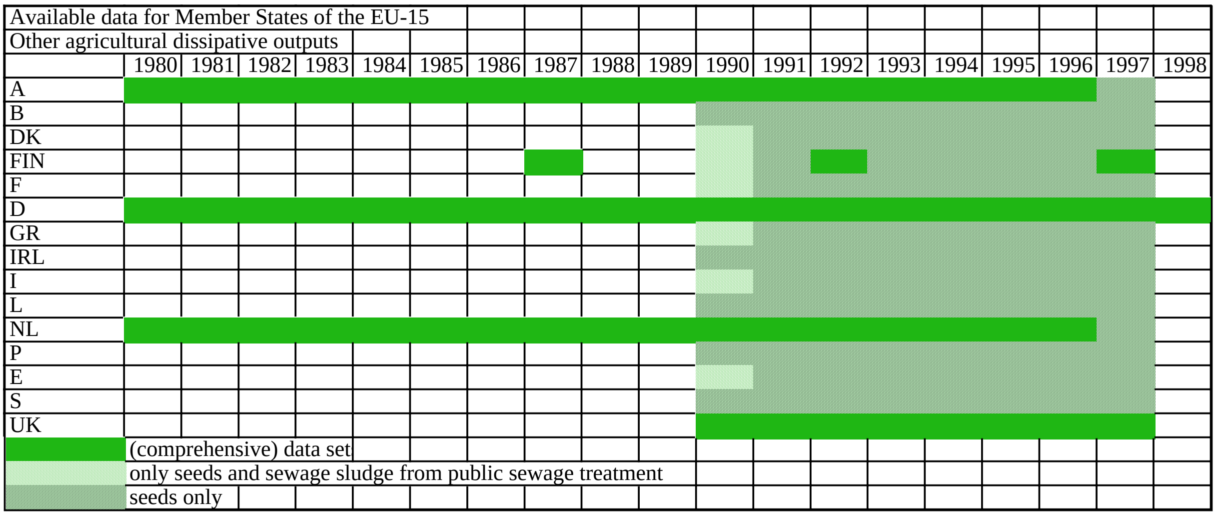


Figure A.18: Data available for EU-15 Member States: other dissipative outputs

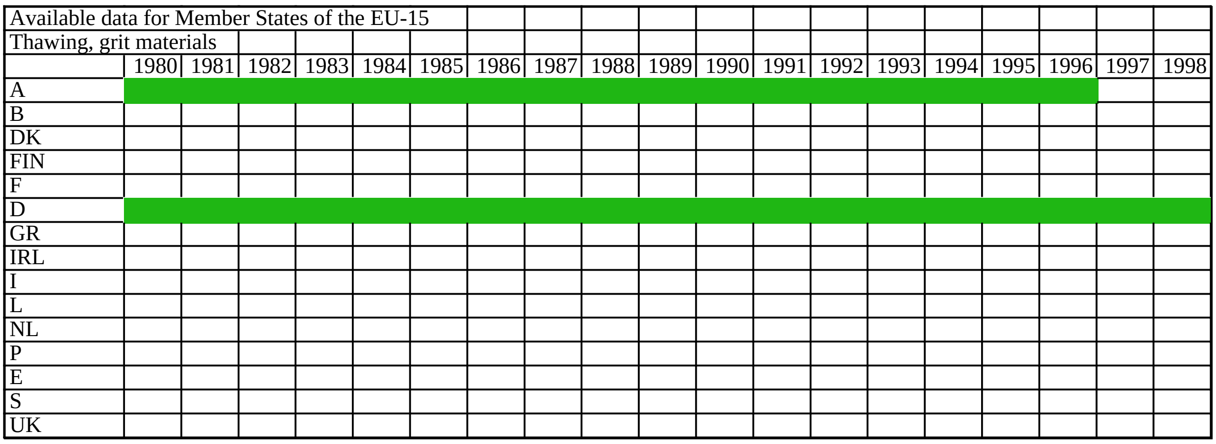


Figure A.19: Data available for EU-15 Member States: dissipative losses

Available data for Member States of the EU-15																			
Dissipative losses																			
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
A																			
B																			
DK																			
FIN																			
F																			
D																			
GR																			
IRL																			
I																			
L																			
NL																			
P																			
E																			
S																			
UK																			

Figure A.20: Data available for EU-15 and Member States: all categories of material outputs

Available data for Member States of the EU-15																				
All categories																				
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	better than 1990
A	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	**17**	16	9	9	1995
B	8	4	4	4	4	8	8	8	8	8	12	10	10	10	12	11	11	11	9	
DK	7	6	6	7	7	9	8	9	9	9	11	11	11	12	11	11	11	11	9	1993
FIN	8	4	4	5	5	10	9	13	10	9	13	11	14	11	12	11	11	15	9	1997
F	8	5	5	6	6	9	8	8	8	8	12	12	13	12	12	11	11	11	9	1992
D	**17**	**17**	**17**	**17**	**17**	**17**	**17**	**17**	**17**	**17**	**17**	**17**	**17**	**17**	**17**	**17**	**17**	**17**	**17**	
GR	8	4	4	5	5	8	8	8	8	8	10	10	11	10	11	11	11	10	9	1992,1994-96
IRL	9	4	4	5	6	9	7	8	8	7	11	10	10	10	10	10	10	10	8	
I	8	6	6	7	7	10	9	9	9	9	12	12	11	11	12	11	11	11	9	
L	7	4	4	5	5	9	7	7	7	7	9	10	9	10	10	10	10	10	8	1991,1993-97
NL	12	11	11	11	11	12	12	12	12	12	15	15	15	15	15	15	15	10	9	
P	8	4	4	6	5	8	8	8	8	8	9	10	11	10	10	11	10	9	8	1992, 1995
E	7	4	4	5	5	8	8	9	9	9	11	11	12	11	11	11	11	10	9	1992
S	8	4	4	5	5	8	8	8	9	8	12	10	10	11	11	11	10	10	9	
UK	8	6	6	8	7	10	8	9	10	10	14	13	14	14	14	14	14	15	12	1997
EU-15	139	99	99	112	111	151	141	149	148	145	**184**	178	**184**	180	**184**	182	179	169	143	
EU: % of maximum score	55%	39%	39%	44%	44%	59%	55%	58%	58%	57%	**72%**	70%	**72%**	71%	**72%**	71%	70%	66%	56%	
Maximum score is 17 annualy by MS																				
Maximum score is 255 annualy by EU-15																				

Figure A.21: Data available for EU-15 Member States: categories missing in 1990 and eventually other availability

Available data for Member States of the EU-15								
Categories missing in 1990 and availability in (an)other year(s) or not (completely) available at all (NA)								
	HFC,PFC,SF6	PM10, Dust	Emiss. to water	Waste	Pesticides	Other agricult.	Thawing/grit mat.	Diss. Losses
A	95.98							
B			NA	94		NA	NA	NA
DK		NA	NA	93		NA	NA	NA
FIN			87,92,97			87,92,97	NA	NA
F			NA	92		NA	NA	NA
D								
GR		NA	NA	92	80,86-89,94-96	NA	NA	NA
IRL	NA		NA	84		NA	NA	NA
I			NA	91.94		NA	NA	NA
L	NA	85	NA	93	91,94-97	NA	NA	NA
NL							NA	NA
P	95	80	NA	92	91-96	NA	NA	NA
E		NA	NA	92		NA	NA	NA
S	94,95,97,98		NA			NA	NA	NA
UK				89,97,98			NA	NA

A.2. Accounting for material balances of EU-15

A.2.1. Introduction and overview

The concept of material flow accounting (MFA) refers to material inputs to and material outputs from an economy (see also chapter 1). Material inputs may come from domestic extraction and harvest and from abroad (imports). Material inputs comprise direct material inputs (DMI) as well as hidden, indirect or unused flows[28]. All together, these material inputs make up the Total Material Requirement (TMR) of an economy, i.e. its physical basis for production. Material outputs of an economy comprise exports (whose hidden flows may also be taken into account) and material outputs to the environment in the form of emissions and wastes. The latter may be divided into domestic processed outputs (DPO, which are emissions to air and water, landfilled waste and dissipative uses of products and dissipative losses) and domestic hidden flows which add up to Total Domestic Output (TDO). Taking additional material flows (balancing items) on the input and output side into account allows to account for the net additions to stock (NAS) by the difference between inputs and outputs. Recycling in this concept is a flow occurring within the economy and, thus, is not part of the material resource flow indicators. Material flows described so far refer to materials excluding water except for the water contents of the materials. Water withdrawals on the input side and waste water discharges on the output side in general also belong to material resource flows accounting. However, due to their overwhelming quantities as compared to other material flows the inclusion of water in the material flow indicators would not make sense with respect to the interpretation of changes over time and materials productivity which would be dominated by water. It is recommended to perform separate water accounts with derived indicators (see also Eurostat 2001).

The technical descriptions in this annex will follow the general concept and framework described above and present step by step the full details of the accounting up to the final aggregation of major material flow indicators.

The concept of „Total Material Requirement -TMR“ had originally been developed at the Wuppertal Institute under the label „Total Material Input - TMI“ (for a recent overview see Bringezu 2000). The TMR of national economies comprises two major components, i.e. domestic material flows and foreign material flows (Adriaanse et al. 1997, 1998). These are further subdivided into direct material inputs (DMI) and hidden material flows which had originally been called „ecological rucksacks“ in the MIPS-concept (Schmidt-Bleek et al. 1998). TMR and its sub-components are set into relation with GDP and population size to obtain the material productivity or material intensity of GDP of the economy, and the total material flows per capita, respectively. Both are aggregate measures for the total environmental impact of national or regional economies.

The basic structure of TMR is reflected in its basic accounting components of first order:

- Domestic (material flows)
- Foreign (material flows)

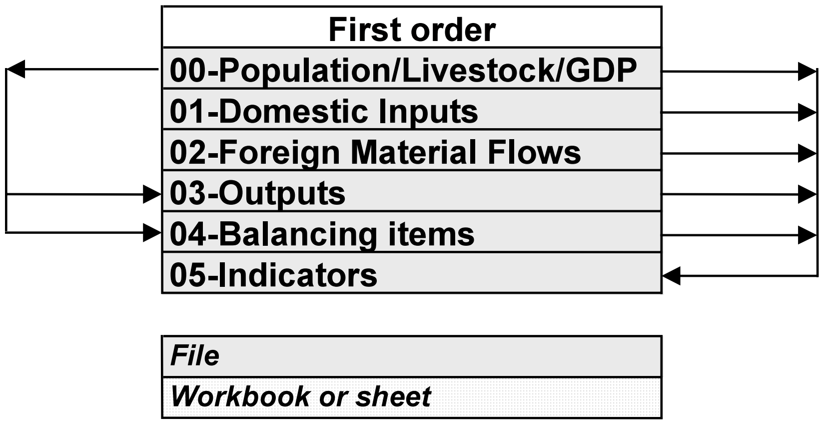
Overall economy-wide material flow accounting including material inputs and material outputs was developed in parallel by research institutes in Austria, Japan and Germany. The accounting of

[28] Originally, the term ecological rucksack, or simply rucksack, had been created to characterise the life-cycle-wide material requirements excluding the mass of the product under consideration (Schmidt-Bleek 1993, for an overview see Schmidt-Bleek et al. 1998). In subsequent studies on economy-wide material flow accounting the terms hidden flows (Adriaanse et al. 1997, Matthews et al. 2000, Bringezu and Schütz 2001a and b), and indirect material flows (Eurostat 2001) have been used. For more details see chapter 1.

material outputs of an economy and its net additions to stock has recently been performed in an international study (Matthews et al. 2000). As a consequence of all these pioneering studies Eurostat had established in 2000 a task force on material flow accounting which came up with a methodological guide for performing economy-wide material flow accounts with derived resource use indicators (Eurostat 2001). The present study builds upon these international standards.

Figure A.22 gives an overview of the first order files differentiated to structure data for material flow accounting (MFA) of the EU. More details will be described in the respective chapters of this annex. Transfer of data by automatic links from one file, worksheet or workbook to another are indicated by arrows. This overview will be the reference for the further description of the methodology of MFA in the following chapters. It is also meant to provide an easy access to those who will further use the data for studies and applications.

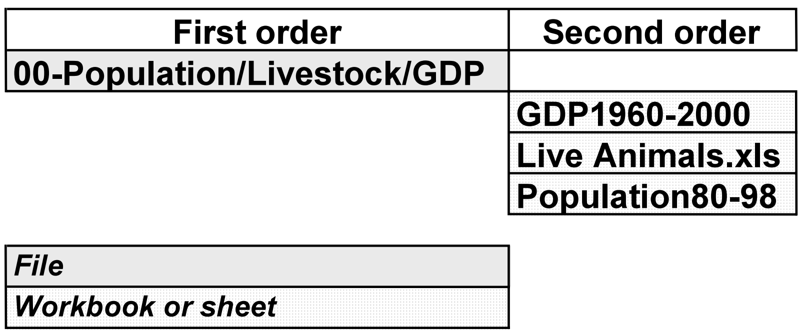
Figure A.22: Overview of files for material flow accounting (MFA) of the EU.



A.2.2. General data

General data usually set into relation with material flows (Adriaanse et al. 1997) are the population (capita) and the gross domestic product of economies (GDP). Livestock numbers are needed to estimate manure (domestic outputs) and respiration (balancing items). These data for the EU are organised under the file „00-Population/Livestock/GDP“ (FIGURE A.23).

Figure A.23: Overview of files, workbooks or worksheets for general data of the EU.

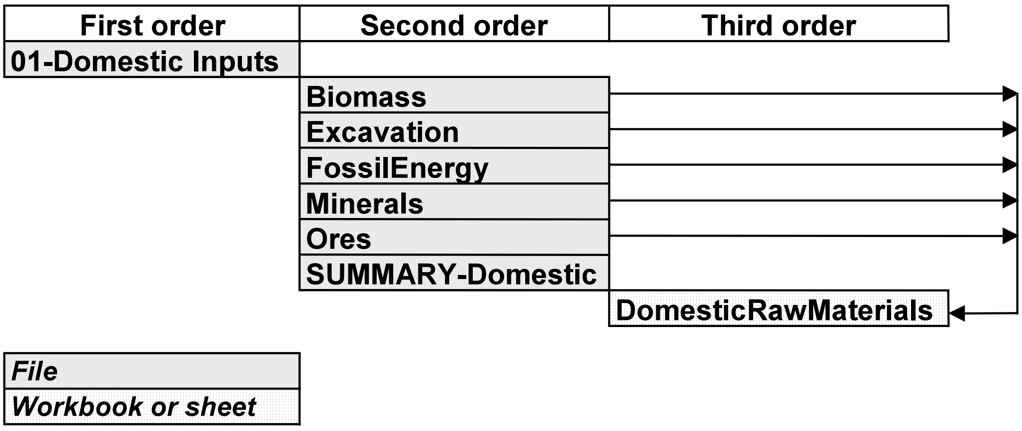


GDP data were taken from Eurostat statistics in 1990 constant ECU. Population data were taken from Eurostat statistics or FAOSTAT. Livestock numbers were from FAOSTAT.

A.2.3. Domestic material input flows

The following chapters will give descriptions of data and methods for the step-by-step accounting of domestic material flows of EU-15 as shown in Figure A.24.

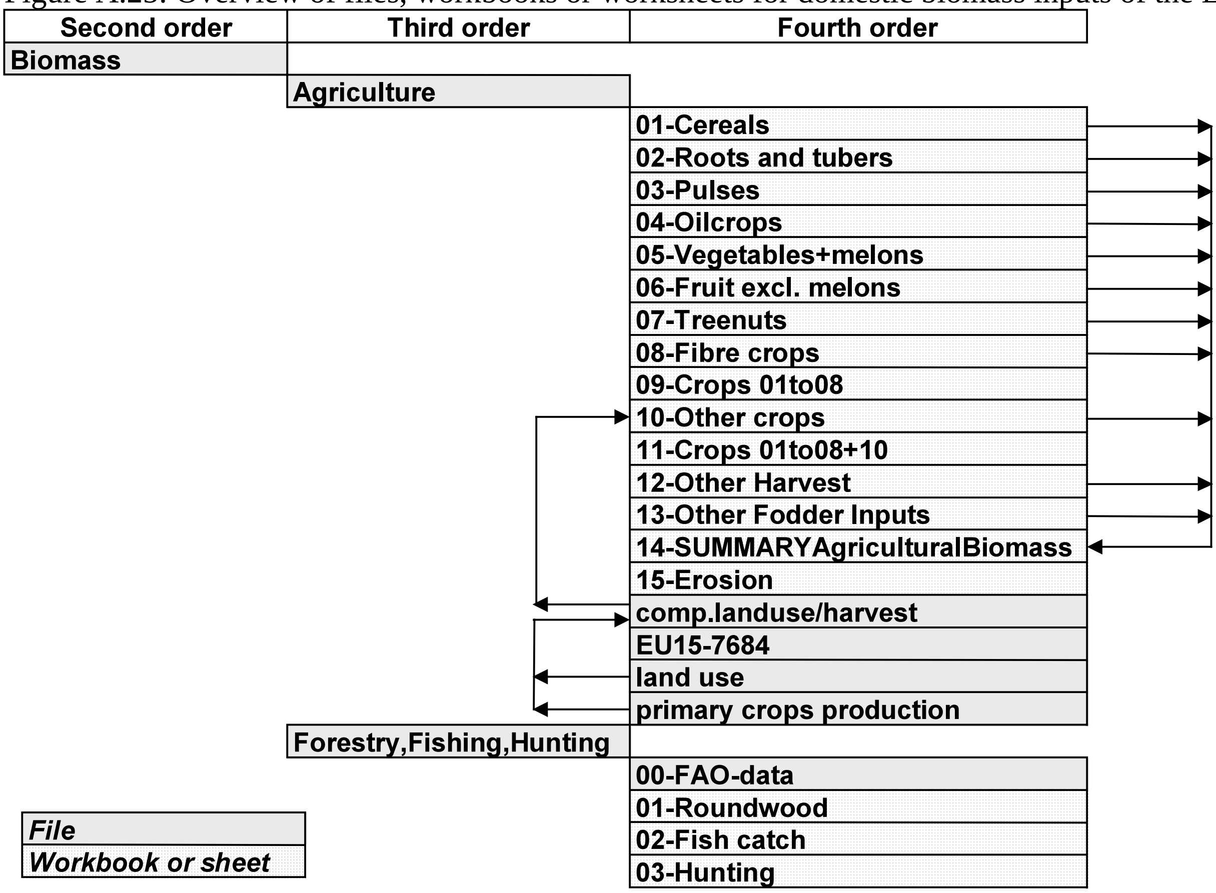
Figure A.24: Overview of files, workbooks or worksheets for domestic material inputs of the EU.



A.2.3.1. Biomass

For easy access to data the service on the homepage of FAO (http://apps.fao.org) was used to download data on harvested biomass and land-use in agriculture, for roundwood production in forestry, and for the amount of biomass from fishing (FIGURE A.25).

Figure A.25: Overview of files, workbooks or worksheets for domestic biomass inputs of the EU.



A.2.3.1.1. Agriculture

File *„primary crops production"* contains for the EU and all Member States 1976 to 1999 all primary crops production data available from the database of FAO under „http://apps.fao.org". These data are grouped under the main headings in worksheets *01-cereals to 08-fibre crops* and *10-other crops* (see also TABLE A.3). Corresponding data for land use by primary crop production are found in file *„land use"* organised as for production data. A comparative analysis of land use in hectares and production in tonnes is made for primary crops in file *„comp.landuse/harvest"*. The main reason for this is to estimate missing production data for green fodder under *„other crops"* for data prior to 1985. This estimation procedure was done as follows:

- Basis for the estimate is the detailled listing of all primary crops of a Member State in parallel for area und production in time series. By this, statistical breaks become quite obvious. In cases of good statistics (as e.g. for Austria) the sums of land use of primary crops equal the total of cropland comprising arable land and permanent crops. In case of the afore mentioned statistical breaks this is not the case. In those cases the procedure is as follows: (1) land-use for missing primary crops (e.g. alfalfa, pumpkins, rye grass for France) is estimated according to the %-share of total cropland reported in 1985. (2) the yields 1980-84 are estimated by using the averages of the years following to 1985. (3) the production is estimated by multiplication of (1) with (2).

The estimates for missing other primary crops are transfered to worksheet *„10-Other crops"*.

File *„EU15-7684"* contains the primary crop data for EU-15 and Member States from 1975 to 1984.

In each worksheet for primary crops a summary table is made with respect to the distribution among the member states, and another summary table is made with respect to the aggregate of the nine main groups for EU-15. These summary tables are marked (in light yellow by Member Countries and light blue by main material groups) for easy identification within the worksheet. They are transfered to the worksheet *„14-SUMMARYAgriculturalBiomass"*.

In addition to biomass reported to be harvested by agricultural statistics, there are biomass inputs which are not reported there but nevertheless occuring (worksheet *„12-Other Harvest"*):

- Sugar beet leaves
- Fodder beet leaves
- Straw input
- Catch crops

Sugar beet leaves used as feed from domestic production for agricultural animals are reported in statistics of the German Ministry of Nutrition, Agriculture and Forestry, the ratio of leaves to beets being about 0.67. This multiplier was used to account for the input of sugar beet leaves in EU-15 based on the data for sugar beet harvested in Member States. The same procedure was done for fodder beet leaves, the ratio of leaves to beets being about 0.23 in that case. It was also done for straw from grains production using a ratio of 0.46 of straw to grains (under the assumption that 50% of total straw production was used as an input for further processing).
Catch crops are also reported under feedstuffs from domestic production for agricultural animals in statistics of the German Ministry of Nutrition, Agriculture and Forestry. No specific information was available for other EU-15 member states, so only the German data were used.

Agricultural biomass represented in harvest statistics mostly refer to crops cultivated on arable land and permanent cropland. The third main category of agricultural land use, the permanent pastures, may either be harvested to produce animal feedstuff or may be used for grazing of animals. The first use is represented in statistics. The latter use, which may be characterised as harvested by animals, is a used material input flow just as harvested biomass by machinery is, but not represented in harvest statistics. To account for this input the following procedure was performed (worksheet „*13-Other Fodder Inputs*“):

- first, all the biomass categories from harvest statistics which were attributable to permanent pastures were filtered out. These were: alfalfa for forage and silage, clover for forage and silage, forage products nes (not elsewhere specified), grasses nes for forage and silage, and rye grass for forage and silage. The total land use of these categories was substracted from the total area of permanent pastures,
- second, the remaining area of permanent pastures was the basis for an estimate of the related input of green biomass by animals' grazing. Consequently, yield coefficients had to be found in order to account for the input of biomass by grazing in tonnes where direct data were not available,
- third, direct data for the input of biomass by grazing was derived from German feedstuffs statistics of the Ministry of Nutrition, Agriculture and Forestry. They corresponded to yields in between about 12 to 15 tonnes per hectare permanent pasture. For Austria, the total amount of feedstuff by grazing was available from the database of the Institute for Interdisciplinary Research and Continuing Education in Vienna (IFF), and these figures were directly used. For the UK specific estimates were performed during the study on Total Material Resource Flows and integrated in the present database,
- fourth, for the remaining territory of the EU the German yields were multiplied with the area of non-harvested permanent pastures. The result was an estimate for the input of fodder biomass by grazing of agricultural animals.

The total domestic direct material input by agriculture is summarised in worksheet „*14-SUMMARYAgriculturalBiomass*“.

TABLE A.3: Main groups and categories of biomass from agricultural harvest

01	02	03	04	05	06	07	08	09
Cereals	**Roots and Tubers**	**Pulses**	**Oilcrops**	**Vegetables&Melons**	**Fruit excl. Melons**	**Treenuts**	**Fibre Crops**	**Other crops**
Barley	Potatoes	Beans, Dry	Groundnuts in Shell	Artichokes	Apples	Almonds	Cotton Lint	Alfalfa for Forage+Silag
Buckwheat	Roots and Tubers Nes	Broad Beans, Dry	Hempseed	Asparagus	Apricots	Chestnuts	Flax Fibre and Tow	Anise, Badian, Fennel
Canary Seed	Sweet Potatoes	Chick-Peas	Linseed	Beans, Green	Avocados	Hazelnuts (Filberts)	Hemp Fibre and Tow	Beets for Fodder
Cereals Nes	Yams	Lentils	Melonseed	Broad Beans, Green	Bananas	Nuts Nes		Cabbage for Fodder
Maize		Lupins	Mustard Seed	Cabbages	Berries Nes	Pistachios		Carrots for Fodder
Millet		Peas, Dry	Oilseeds Nes	Cantaloupes&oth Melons	Blueberries	Walnuts		Chicory Roots
Mixed Grain		Pulses Nes	Olives	Carrots	Carobs			Clover for Forage+Silage
Oats		Vetches	Poppy Seed	Cauliflower	Cherries			Cottonseed
Rice, Paddy			Rapeseed	Chillies&Peppers, Green	Citrus Fruit nes			Forage Products Nes
Rye			Safflower Seed	Cucumbers and Gherkins	Currants			Grasses Nes,Forage+Silag
Sorghum			Seed Cotton	Eggplants	Dates			Hay (Unspecified)
Triticale			Sesame Seed	Garlic	Figs			Hops
Wheat			Soybeans	Green Corn (Maize)	Fruit Fresh Nes			Leguminous Nes,For+Sil
			Sunflower Seed	Leeks and Oth.Alliac.Veg	Fruit Tropical Fresh Nes			Maize for Forage+Silage
				Lettuce	Gooseberries			Peppermint
				Mushrooms	Grapefruit and Pomelos			Pimento, Allspice
				Onions+Shallots, Green	Grapes			Pumpkins for Fodder
				Onions, Dry	Kiwi Fruit			Pyrethrum, Dried Flowers
				Peas, Green	Lemons and Limes			Rye Grass,Forage+Silage
				Pumpkins, Squash, Gourds	Oranges			Sorghum for Forage+Silag
				Spinach	Peaches and Nectarines			Spices Nes
				String Beans	Pears			Sugar Beets
				Tomatoes	Persimmons			Sugar Cane
				Vegetables Fresh Nes	Pineapples			Swedes for Fodder
				Watermelons	Plums			Tea
					Quinces			Tobacco Leaves
					Raspberries			Turnips for Fodder
					Sour Cherries			Vegetables+Roots,Fodder
					Stone Fruit Nes, Fresh			
					Strawberries			
					Tang.Mand.Clement.Satsma			
Nes = Not elsewhere specified								

Source: FAO database (http://apps.fao.org), own compilation

Erosion of soil from arable land was estimated for the following categories of land use (worksheet „*15-Erosion*“):

- Roots and tubers
- Sugar beets
- Fodder beets
- Maize for fodder
- Arable land excl. maize, roots and tubers, sugar and fodder beeets

Erosion rates shown in TABLE 4 were used to account for estimates of soil erosion from arable land (all from database of Wuppertal Institute). Data for soil erosion in Finland were taken directly from the database of Thule Institute at University of Oulu, Finland (Juutinen and Mäenpää 1999). Data for soil erosion in the Netherlands were taken directly from the Resource Flows study (Adriaanse et al. 1997). For the UK specific estimates were performed during the study on Total Material Resource Flows.

TABLE A.4: Erosion rates (tonnes per ha) for estimates of soil erosion from arable land

	Roots and tubers	Sugar beets	Fodder beets	Maize for fodder	Other arable land
EUR 15	**17**	**17**	**17**	**51**	**14**
Belgium	13	13	13	38	10
Denmark	6	6	6	19	5
Greece	31	31	31	94	25
Spain	31	31	31	94	25
France	13	13	13	38	10
Ireland	6	6	6	19	5
Italy	19	19	19	56	15
Portugal	31	31	31	94	25
United Kingdom	11	11	11	34	9
Austria	19	19	19	56	15
Sweden	6	6	6	19	5
Germany	10	10	10	30	8

A.2.3.1.2. Forestry, Fishing, Hunting

The data for this group of domestic material inputs were organised in the following way:
01-Roundwood
02-Fish catch
03-Hunting

Data for raw material input from forestry (worksheet: „*01-Roundwood*“) were downloaded from the FAO website (http://apps.fao.org). The total volume of roundwood was differentiated by three kinds

- coniferous roundwood
- non-coniferous roundwood
- wood for charcoal

Data are reported in cubicmetres roundwood excluding barks. They were converted to tonnes using the following coefficients, derived from German statistics: coniferous roundwood: 0.75 tonnes per m^3, non-coniferous roundwood: 0,85 tonnes per m^3, and wood for charcoal: 0.8

tonnes per m^3. Besides data for Germany (from the database of Wuppertal Institute), original data for total roundwood input were also available in tonnes for Austria (database of the Institute for Interdisciplinary Research and Continuing Education in Vienna - IFF), for Finland (database of Thule Institute at University of Oulu, Finland, Juutinen and Mäenpää 1999), for Sweden (Isacsson et al. 2000) and for the UK. These were directly employed in the database instead of converting FAO data from m^3 to tonnes.

Data for raw material input from fishing (worksheet: „*02-Fish catch*“) were also downloaded from the FAO website (http://apps.fao.org). Total fish catch and its sub-category total marine fish catch were differentiated, the difference being attributed to the category „other aquatic catch excluding mammals“. For Finland data on wild fish catch were taken from the database of Thule Institute at University of Oulu, Finland (Juutinen and Mäenpää 1999), instead of the FAO data. The hidden flows of fish catch were estimated according to a study of Greenpeace (reported in: Frankfurter Rundschau of 6 November 1999) after which 25% of the catch is being discarded on board (by-catch). For the UK study a more detailed analysis of dead discards in the Crangon fishery were included in the database.

Data for raw material input from hunting (worksheet: „*03-Hunting*“) have so far been quantified for Germany (database of Wuppertal Institute, see also Schütz and Bringezu 1998). No other source could be found reporting about this type of input in other EU-15 member states.

A.2.3.2. Excavation and dredging

Data for this type of hidden flows comprise excavations for infrastructures and dredging for navigation purposes. They are organised in a single worksheet called „*01-SoilExcavationDomestic*“. In the follow-up to the Resource Flows study (Adriaanse et al. 1997), these material flows have recently been accounted for USA, Japan, The Netherlands, Austria and Germany in time series (Matthews et al. 2000). In addition, these data are available for Finland in time series (database of Thule Institute at University of Oulu, Finland, Juutinen and Mäenpää 1999) and for the UK. Single data for soil excavation were also reported for Belgium in 1992.

To obtain basic coefficients for estimates of excavation flows in other EU-15 member states, these given values were divided by gross value added for constructions (the latter from Eurostat statistics). Resulting coefficients were expressed in the first case as tonnes soil excavated per million ECU gross value added (TABLE A.5). The weighted average for Germany, Netherlands, Austria and Finland was used to estimate soil excavation in tonnes for the remaining member states of EU-15 except Belgium and the UK. Data for the UK were taken from the original database. Coefficients for 1996 were used to account for soil excavation in 1997 as well (except Finland).

TABLE A.5: Soil excavated (tonnes) per million ECU gross value added for constructions

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Belgium								106					
Denmark													
Germany (West) - D	3227	3349	3348	3396	3433	3345							
Greece													
Spain													
France													
Ireland													
Italy													
Luxembourg													
Netherlands - NL	3618	3869	4015	3061	3065	2664	2650	2789	2618	2538	2363	2373	
Portugal													
United Kingdom									923				
Austria - A	5209	5191	5117	4993	4810	4605	4305	4142	4007	3779	3665	3633	
Sweden													
Finland-FIN	8164	8359	8099	7456	6505	6983	8098	11272	12318	10337	6870	6199	5384
GDR													
Germany - D							3823	3337	3416	3613	2991	3035	
Weighted average D,NL,A,FIN	3863	4000	4019	3849	3807	3707	4001	3669	3665	3756	3148	3163	

A similar procedure as for the estimation of soil excavation was performed for dredging. In that case, coefficients obtained for the Netherlands were considered to reflect rather a specific single situation. To obtain estimates for the EU, the German coefficient for 1990 was used (TABLE A.6). Coefficients for 1996 were used to account for dredging in 1997 as well.

TABLE A.6: Dredged material (tonnes) per million ECU gross value added for constructions

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
EUR 15													
Belgium													
Denmark													
Germany (West)						665							
Greece													
Spain													
France													
Ireland													
Italy													
Luxembourg													
Netherlands	9483	7970	7461	6418	5981	6248	5847	5468	5043	4468	3806	3454	
Portugal													
United Kingdom													
Austria													
Sweden													
Finland													
GDR													
Germany													

A.2.3.3. Fossil Energy

The material inputs of this group of fossil energy carriers comprise all inputs obviously used for energetic conversion. The non-energetic use of peat for agriculture was omitted and grouped under minerals. The following sub-categories are counted in separate worksheets named:
01-EnergyHardCoalDomestic
02-EnergyLigniteDomestic
03-EnergyCrudeOilDomestic
04-EnergyNaturalGasDomestic
05-EnergyCrudeOilGasDomestic
06-EnergyPeatFuelDomestic
07-EnergyOilshaleDomestic
08-EnergySUMMARYDomestic
Worksheet „08-EnergySummaryDomestic" takes up the results of worksheets 1 to 7.

Raw material inputs of hard coal were taken from common energy statistics (Eurostat, UN, IEA-OECD) except for Austria which was not reported there. Austrian data (only small amounts of hard coal) were taken from the database of the Institute for Interdisciplinary Research and Continuing Education in Vienna (IFF). Specific ratios for hidden flows to used (marketed) extractions of coal were available from the database of Wuppertal Institute for the UK (1.25 to 6.2 tonnes per tonne from 1970 to 1997), France (0.27 tonnes per tonne), Spain (5.757 tonnes per tonne), and Germany (0.89 to 0.93 tonnes per tonne). These four EU countries held 97% to 100% of the total EU-15 hard coal mining in between 1985 and 1997. Other EU-15 countries were not included in the accounting of hidden flows for hard coal. For comparison, in a study of the German Federal Institution of Geosciences and Raw Materials (BGR 1998) the hidden flow ratio for hard coal was estimated on the global level (covering 91% of global mining) with 3.98 tonnes per tonne saleable coal.

Raw material inputs of lignite (brown coal) were taken from common energy statistics (Eurostat, UN, OECD). Austrian data were taken from the database of the Institute for Interdisciplinary Research and Continuing Education in Vienna (IFF). Specific ratios for hidden flows to used (marketed) extractions of coal were available from the database of Wuppertal Institute for Austria (9 tonnes per tonne), Greece (5 to 11.6 tonnes per tonne), Spain (6.05 tonnes per tonne), and Germany (7.0 to 10.1 tonnes per tonne). These four EU countries held 99% to 100% of the total EU-15 brown coal mining in between 1985 and 1997. Other EU-15 countries were not included in the accounting of hidden flows for lignite.

Raw material inputs of crude oil (petroleum) were taken from common energy statistics (Eurostat, UN, OECD). Austrian data were taken from the database of the Institute for Interdisciplinary Research and Continuing Education in Vienna (IFF). Specific ratios for hidden flows to used (marketed) extractions of crude oil were available from the database of Wuppertal Institute for Germany (0.08 tonnes per tonne), and in general for offshore (0.006 tonnes per tonne) and onshore (0,001 tonnes per tonne) extraction activities, which were attributed to single EU-15 member states.

Raw material inputs of natural gas are reported by common energy statistics (Eurostat, UN, OECD) in energetic units, in this case in Terajoules. The same data sources also report on heat values of natural gases, in kJ per m^3, so that energetic units can be converted to volume units. Finally, these data sources report partly (for some countries) on the density of crude gases in kg per m^3, so that conversion of volume units into tonnes is possible. Densities of crude gases (in kg per m^3) were specifically available for : France 1.021, Netherlands 0.8305, and Germany 0.859248. For the remaining EU-15 member states a density of 0.85 kg per m^3 was assumed. Performing this step-by-step accounting, the crude (net, used) extraction of natural gas by member states of EU-15 was obtained. Austrian data were taken directly from the database of the Institute for Interdisciplinary Research and Continuing Education in Vienna (IFF). German data were taken directly from the database of Wuppertal Institute. Specific ratios for flared or re-injected gas amounts to used (net, crude) extractions of natural gas were derived from information of the World Energy Council in its publication series „World Energy Statistics" (TABLE A.7). These amounts flared or re-injected formed the first part of the hidden flows of natural gas extraction.

The second part of hidden flows of natural gas extraction are drill residues. Hidden flow coefficients were taken from the database of the Wuppertal Institute. They are for:
Onshore Gas Extraction: 0.026 tonnes per tonne net (used, crude) extraction
Offshore Gas Extraction: 0.017 tonnes per tonne net (used, crude) extraction
Unconventional Gas Recovery: 0.012 tonnes per tonne net (used, crude) extraction
Offshore and onshore coefficients were attributed to single EU-15 member states.

TABLE A.7: Ratios of flared and re-injected gases to crude gas extraction.
(tonnes per tonne net (used, crude) extraction

	1987			**1990**		
	Flared	Re-injected	Total	Flared	Re-injected	Total
Denmark	0.125	0.667	0.792	0.103	0.759	0.862
Spain				0.007	0.014	0.021
Italy		0.032	0.032		0.023	0.023
Netherlands				0.001		0.001
United Kingdom				0.052	0.064	0.116
Austria					0.154	0.154
Germany				0.003		0.003

Source: World Energy Council: World Energy Statistics

Raw material inputs of crude oil gas are reported for Germany by statistics of the mining industry, data were taken from the database of the Wuppertal Institute. Crude oil gas is a co-product of natural gas extraction, so, there was no hidden flow assigned.

Raw material inputs of peat for fuel are reported by the UN Industrial (Commodity) Statistics Yearbook. German data were taken from the database the Wuppertal Institute, originating from energy balances (AG Energiebilanzen). A universal hidden flow ratio was 0.25 tonnes per tonne used extraction (Douglas and Lawson 1997).

Raw material inputs of oil shale are reported for Germany by statistics of the mining industry, data were taken from the database of the Wuppertal Institute. No data were available for hidden flows.

A.2.3.4. Minerals

This group of domestic raw materials comprises non-energy and non-metallic minerals which are not counted under fossil energy carriers, respectively ores. The minerals group is organised in the following worksheets:
01-MineralsA,C,E,Domestic
02-MineralsB,Domestic
03-MineralsD,Domestic
04-MineralsPhosphateDomestic
05-MineralsPotashDomestic
06-MineralsSaltsDomestic
07-MineralsBarytesDomestic
08-MineralsFluorsparDomestic
09-MineralsAsbestosDomestic
10-MineralsMagnesiteDomestic
11-MineralsBoratesDomestic
12-MineralsArsenicDomestic
13-MineralsAbrasivesDomestic
14-MineralsGraphiteDomestic
15-MineralsMicaDomestic
16-MineralsOtherDomestic
17-MineralsPeatAgricultDomestic
18-MineralsPyritePyrrhotiteDom
19-Minerals SUMMARY
Worksheet „19-MineralsSummaryDomestic“ takes up the results of worksheets 1 to 18.

Accounting of minerals for EU-15 was based on three data sources: (1) European Minerals Yearbook (EMY), 2nd Edition, 1998, available on the webpage of DG III, (2) UN Industrial Statistics Yearbook (ISY), 1990, 1992, and (3) USGS Minerals Industry Publications for countries available on their homepage. In order to make the accounting compatible with the elaborated material flow accounts in Germany (Environmental and Economic Accounting series of FSOG, and Wuppertal Institute), five classes A, B, C, D and E were introduced and categories were allocated to these (TABLE A.8):
A Sand and Gravel
B Limestone and Dolomite
C Natural stones
D Clays
E Other crude and broken natural stones
The remaining categories were treated as single accounting identities.

Time series of material inputs of minerals were available by UN-ISY from 1981 to 1992, by EMY from 1986 to 1995 and by USGS from 1990 to 1997[29]. Data for Germany (Wuppertal Institute), Finland (Thule Institute at University of Oulu, Finland, Juutinen and Mäenpää 1999), and the UK were taken from their specific databases. Data until 1996 were available for Austria (database of the Institute for Interdisciplinary Research and Continuing Education in Vienna - IFF).

[29] So, the three general data sources overlapped for 1990 to 1992. Data for this period were used to calibrate the entire time series in order to obtain consistent data sets from 1980 to 1997. Data for 1980 were either taken from the specific national databases or by estimation from the UN database starting in 1981.

Raw material inputs of classes A,C and E were counted in the worksheet „01-MineralsA,C,E,Domestic“. The following individual positions were counted:
Crushed Rock Aggregates or Crushed stone
Sand and Gravel
Dimension stone
Slate
Gypsum and Anhydrite
Sulphur
Diatomite
Feldspar
Perlite
Quartz and Quartzite
Silica sand
Talc (and Steatite)
Strontium minerals (Celestite)
Kyanite, andalusite, related materials
Pigments, mineral, natural: iron oxide
Lithium minerals
With the exception of slate (UN-ISY and USGS), all data were from EMY and USGS. Comparing the sum of these categories for Germany with the corresponding total material input in the original German database, the former were by 5% to 20% lower. This seems to be quite acceptable. Still, in the worksheet final data for Germany and other Member States available were replaced by the original ones.

Ratios of hidden flows to commodity inputs for minerals A,C,E were taken mostly from the database of the Wuppertal Institute as follows (in tonnes hidden flows per tonne commodity):

Crushed Rock Aggregates	0.23 (for the UK: chalk, igneous rock and sandstone 0.2)
Sand and Gravel	0.14 for Germany and other EU Member States except the UK which has 0.38
Dimension stone	0.23
Gypsum and Anhydrite	0.2 for the UK
Slate	0.1 to 0.22 for Germany, 19 for the UK
Sulphur	not available, in Germany a by-product of natural gas
Diatomite	0.7 to 1.5, applied only for Germany
Feldspar	0.004 to 0.008, applied only for Germany
Silica sand	0,00018 in 1991; 0,012 in 1993 in Germany, 0.75 in the UK
Talc (and Steatite)	around 0.45 for Germany, 0.2 for the UK

So, for the first three, quantitatively dominating materials, hidden flows were calculated on EU-15 level. As for direct material inputs, the German numbers obtained from the accounting described were subsequently replaced by the original ones.

Raw material inputs of class B were counted in the worksheet „02-MineralsB,Domestic“. In that case, the EMY does not provide data but characterises the situation as „no reliable statistics available“. So, data were taken from the UN-ISY and from USGS. The ratio of hidden flows to limestone and dolomite was taken from the database of the Wuppertal Institute, it is 0.33 tonnes per tonne. For the UK a hidden flow coefficient of 0.2 was used (Douglas and Lawson 2001).

Raw material inputs of class D, i.e. clays, were counted in the worksheet „03-MineralsD,Domestic“. The UN industrial commodity statistics yearbook (UN-ICSY) reports total production of clays from 1985 to 1992. The European Minerals Yearbook (EMY) reports data on four positions of clays, i.e. common or structural clays, kaolin, refractory clays and sillimanite minerals, and bentonite, sepiolite & attapulgite, which were summed up to total clays according to EMY. USGS reports on clays as shown under remarks in Table A.8. For the accounting of domestic inputs of clays in EU-15, the three data sets were combined in a first step, using data from UN-ICSY from 1985 to 1992, data from EMY from 1993 to 1995, and USGS data from 1990 to 1997. The resulting data represented therefore the total of clays reported by official international statistics. For the accounting of the total used extraction of clays by EU-15, these official data for the total were checked for consistency by a step-by-step procedure, taking into account that clays typically consist of two main groups, special clays for industrial manufacturing (like kaolin), and common clays for construction materials (like bricks).

First, the material inputs of special clays were counted by the following groups (named sub-positions 1 to 4 of position 1, i.e. total clays, in the worksheet):

bentonite, and bentonite, sepiolite & attapulgite,

fuller's earth,

kaolin,

andalusite, kyanite and sillimanite, fire clay, and refractory clays and sillimanite minerals.

Second, the sum of these four clays was substracted from the total input of clays obtained as described before. Using the same statistical sources, the difference between total clay input and the four types of special clays therefore resulted in the material input of other clays, assumed to be identical with common clays for construction materials (sub-position 5 of position 1 in the worksheet).

TABLE A.8: Accounting of minerals by commodities and data sources.

Classifications and Data for Minerals								
	1. European Minerals Yearbook			**2. UN Industrial Statistics Yearbook**			**3. USGS The Mineral Industry of _**	
	Positions:	**Classes**		**Positions:**	**Classes**		**Positions:**	**Classes**
1	Crushed Rock Aggregates	**C**	1	Gravel and crushed stone	**A,C**	1	Stones	**A,B,C**
2	Sand and Gravel	**A**	2	Sand, silica and quartz	**A**	2	Sand and Gravel	**A**
3	Dimension stones	**C**	3	Marble, travertines etc.	**C**	3	Dimension stones	**C**
4	Calcium carbonate and dolomite	**B**	4	Granite, porphyry, basalt, sandstone etc.	**C**			
			5	Limestone and calcerous stone	**B**	4	Limestone	**B**
			6	Dolomite	**B**			
			7	Chalk	**C**			
5	Slate	**C**	8	Slate	**C**	5	Slate	**C**
6	Common or structural clays	**D**	9	Clays, total production	**D**	6	Clays	**D**
7	Cement							
8	Gypsum and Anhydrite	**C**	10	Gypsum	**C**	7	Gypsum and Anhydrite	**C**
9	Lime							
10	Phosphate rock		11	Natural phosphates		8	Phosphates, crude	
11	Potash		12	Potash		9	Potash	
12	Salt		13	Salt unrefined		10	Salt by sub-types	
13	Sulphur	**C**	14	Sulphur	**C**	11	Sulphur	
14	Barite		15	Barytes		12	Barite	
15	Fluorspar		16	Fluorspar		13	Fluorspar	
16	Kaolin	**D**						
17	Refractory clays and Sillimanite minerals	**D**						
18	Bentonite, Sepiolite and Attapulgite	**D**						
19	Asbestos		17	Asbestos		14	Asbestos, ore	
20	Diatomite	**E**				15	Diatomite	**E**
21	Feldspar	**C**				16	Feldspar	**C**
22	Magnesite		18	Magnesite		17	Magnesite, crude	
23	Perlite	**E**				18	Perlite	**E**
24	Quartz and Quartzite	**A,C**				19	Quartz and Quartzite	**A,C**
25	Silica sand	**A**						
26	Talc	**E**	19	Talc	**E**	20	Talc and steatite	**E**
			20	Borate minerals		21	Borate minerals	
			21	Arsenic		22	Arsenic	
			22	Abrasives		23	Abrasives	
			23	Graphite		24	Graphite	
			24	Diamonds, industrial				
			25	Diamonds, gems				
			26	Mica		25	Mica	
			27	Peat for fuel		26	Peat for fuel	
			28	Peat for agricultural use		27	Peat for agricultural, horticultural and other use	
						28	Pyrite and pyrrhotite	
						29	Strontium minerals	
						30	Kyanite, Andalusite, related materials	
						31	Pigments, mineral, natural: Iron oxide	
						32	Lithium minerals	
	Classes:							
	Source: German Production and Mining Statistics							
Classes								
A	Sand and Gravel							
B	Limestone and Dolomite							
C	Natural stones							
D	Clays							
E	Other crude and broken natural stones							
	Commodities not found here (but in German sources):							
	Oil shale							
	Other products from mining and similar products							
Sources								
1. European Minerals Yearbook, 2nd Edition, 1998								
2. UN Industrial Statistics Yearbook, 1990, 1992								
3. USGS The Mineral Industry of _								
	Remarks:			**Remarks:**			**Remarks:**	
1	2/3 sedimentary rocks (limestone, dolomite), other 1/3: igneous rock (basalt, diabase etc.) or metamorphic rock (gneiss, marble, quartzite, schist, slate, etc.)		1			1	Dolomite, Alabaster, Marble, Granite, Porphyr Sandstone, Soapstone, Flysch, Marl, Marl for cement, Serpentine, Basalt, Diorite, Gabbro, Graywacke, Ophite, Schist, Syenite, Sepiolite, Chalk, Phonolite, Olivine, Calcite, Chert and flint, Igneous rock, other stone.	
2			2			2		
3	Marble and Granite		3			3	Distinction to crushed stones is not always given.	
4			4			4		
5	No Data		5	excl. dolomite and chalk		5		
6			6	No Data		6	Kaolin and kaolinitic clay and earth, crude; fire clay; bentonite, crude; refractory clay, unspecified, excl. kaolinitic earth; fuller's earth attapulgite; other clays.	
7	Not a Raw Material !		7			7		
8			8	excl. roofing slate		8		
9	Not a Raw Material !		9	contains 6, 16, 17 and 18 of EMY-categories		9		
10			10			10		
11			11			11	characterised as a by-product of natural gas, petroleum or unspecified sources.	
12			12			12		
13			13			13		
14			14			14		
15			15			15		
16			16			16		
17	Sillimanite, kyanite, andalusite and other polymorphs		17			17		
18			18			18		
19			19			19		
20			20	Germany: data possibly in other aggregates		20		
21			21	By-product of nickel, silver, pyrites		21		
22			22	Puzzolan, pumice, volcanic cinder, Germany data possibly in other aggregates		22		
23			23			23		
24	No Data		24	No Extraction in EU-15		24		
25			25	No Extraction in EU-15		25		
26	incl. soapstone		26	Al-silicates		26		
			27			27		
			28			28		
						29		
						30		
						31		
						32		

Third, data thus obtained for the input of common clays for construction materials were checked for consistency by the following procedure: the amount of clays necessary for the production of construction materials was estimated from data on the production of these materials and the corresponding input of clays. The production of construction materials from clays was accounted for the following products (all data from UN-ICSY):
Building bricks, made of clay (ISIC 3691-01B)
Tiles, roofing, made of clay (ISIC 3691-04A)
Tiles, roofing, made of clay (ISIC 3691-04B)
Original data for these three support-positions were given in 1000 m^3 (some data are given directly in 1000 tonnes), million units, respectively million m^2. They were converted to tonnes by the following coefficients (derived from German production statistics of FSOG): 2 tonnes per m^3, 2,73 kg per unit, and 220 kg per m^2. The raw material input of clay for the production of bricks and tiles was accounted by the following coefficients (from Klinnert 1993): 1.1 tonnes clay per tonne bricks, and 1.0 tonnes clay per tonne tiles. Then, the resulting clay input for the production of the three sub-positions was summed up. This sum was substracted from the numbers obtained for the input of clays for construction materials as described before (sub-position 5 of position 1 in the worksheet). So, in the ideal case, the difference should be (close to) zero.

Fourth, for a synthesis of the described accounting results, the following conventions were set up:
Special clays were accounted for separately: bentonite, fuller's earth, kaolin, andalusite etc. (step 1)
Common clay for the production of bricks and tiles is accounted for as described above (step 3), but data are taken only if they are higher than those resulting from the difference between total clays and special clays (step 2).
Data obtained following these rules 1 and 2 represented the used extraction of all clays in EU-15 (total clay input). Finally, data for the inputs of clays for Germany (Wuppertal Institute), Austria (Institute for Interdisciplinary Research and Continuing Education in Vienna - IFF) and The Netherlands (Resource Flows study - Adriaanse et al. 1997) were replaced by data from original country studies.

To account for the hidden flows of clays the following coefficients were used (in tonnes hidden flows per tonne commodity):

bentonite:	3 for the UK
fuller's earth:	0.004 to 0.017 for Germany, 3 for the UK
kaolin (china clay):	0.57 to 1.78 for Germany, 8 for the UK
andalusite, kyanite and sillimanite, refractory clays:	not available
common (other) clays:	0.31 to 0.36 for Germany, 0.25 for other EU member states

Raw material inputs of natural phosphates were counted in the worksheet „04-MineralsPhosphateDomestic". Data in gross weights were taken from UN-ICSY (1985 to 1992), EMY (1993 to 1995), Statistical Yearbook for Foreign Countries of FSOG (1996-1997), and USGS until 1997. A universal coefficient of 12.02 was used to account for hidden flows (weighted average for global extraction by open-pit mining and other types of mining; source: Krauss, H., Saam, H.G., Scjmidt, H.W., Phosphate - Summary report,).

Raw material inputs of crude potash salts were counted in the worksheet „05-MineralsPotashDomestic". Data were taken from UN-ICSY (1985 to 1992), from EMY (1993 to 1995), and from USGS until 1997. German data were compared with numbers from official

German statistics (production statistics of FSOG, mining statistics of the mining authorities of the Federal States, annual reports of the German Federal Institution of Geosciences and Raw Materials) reporting on:
Potash crude salts extraction: total
Potash crude salts extraction: used
Potash crude salts extraction: K_2O-content
Potash salts extraction marketable: K_2O-content
Thus, it was found out that values for Germany in UN-Statistics until 1992 and in EMY from 1993 on refered to crude extraction in K_2O-content, and values in EMY for West-Germany 1986 to 1990 refer to marketable K_2O-contents only. German data were then replaced by the official ones for the extraction of used crude salts. Because data of UN and EMY for France were characterised as recovered quantities of K_2O, the average German multiplier to account for total used extraction was applied to derive the used extraction of potash salts in France. The coefficients for hidden flows in Germany (in tonnes hidden flows per tonne commodity) were between 3.6 and 5.7, only hidden flows for Germany were counted.

Raw material inputs of crude salts were counted in the worksheet „06-MineralsSaltsDomestic“. Data were taken from UN-ICSY, from EMY, and from USGS. German data were replaced by numbers from official German statistics (production statistics of FSOG, mining statistics of the mining authorities of the Federal States, annual reports of the German Federal Institution of Geosciences and Raw Materials) reporting on:
rock salt
industrial brine
boiled salt
The coefficients for hidden flows in Germany (in tonnes hidden flows per tonne commodity) were between 0.034 and 0.055, only hidden flows for Germany were counted.

Raw material inputs of barytes were counted in the worksheet „07-MineralsBarytesDomestic“. Data were taken from UN-ICSY (1985 to 1990), from EMY (1991 to 1995), and from USGS. German data were compared with numbers from official German statistics (production statistics of FSOG, mining statistics of the mining authorities of the Federal States, annual reports of the German Federal Institution of Geosciences and Raw Materials) reporting on total and used extractions. The coefficients for hidden flows in Germany (in tonnes hidden flows per tonne commodity) were between 0.36 and 0.78, for the UK it was 1 (Douglas and Lawson 2001). No other hidden flows were counted.

Raw material inputs of fluorspar (excluding precious stones) were counted in the worksheet „08-MineralsFluorsparDomestic“. Data were taken from UN-ICSY, from EMY, and from USGS. German data were replaced by numbers from official German statistics (production statistics of FSOG, mining statistics of the mining authorities of the Federal States, annual reports of the German Federal Institution of Geosciences and Raw Materials) reporting on total and used extractions. The coefficients for hidden flows in Germany (in tonnes hidden flows per tonne commodity) were between 1.03 and 1.76, for the UK it was 1 (Douglas and Lawson 2001). No other hidden flows were counted.

Raw material inputs of asbestos were counted in the worksheet „09-MineralsAsbestosDomestic“. Data were taken from UN-ICSY, from EMY, and from USGS. No hidden flows were counted.

Raw material inputs of magnesite were counted in the worksheet „10-MineralsMagnesiteDomestic“. Data were taken from UN-ICSY from EMY, and from USGS. No hidden flows were counted.

Raw material inputs of crude borate minerals were counted in the worksheet „11-MineralsBoratesDomestic“. Data were taken from UN-ICSY. No hidden flows were counted.

Raw material inputs of arsenic were counted in the worksheet „12-MineralsArsenicDomestic“. Data were taken from UN-ICSY. No data were reported for EU-15. Arsenic is typically obtained by roasting arseniferous ores of nickel and silver or arsenical pyrites, it seems to be a by-product, contained in the rucksacks of these ores, so, it is not counted as an input here.

Raw material inputs of natural abrasives (pozzolan, pumice, lapilli, emery) were counted in the worksheet „13-MineralsAbrasivesDomestic“. Data were taken from UN-ICSY and from USGS. No hidden flows were counted.

Raw material inputs of natural graphite were counted in the worksheet „14-MineralsGraphiteDomestic“. Data were taken from UN-ICSY and from USGS. German data were replaced by numbers from official German statistics (production statistics of FSOG, mining statistics of the mining authorities of the Federal States, annual reports of the German Federal Institution of Geosciences and Raw Materials) reporting on total and used extractions. The coefficients for hidden flows in Germany (in tonnes hidden flows per tonne commodity) were between 0.63 and 0.88, only hidden flows for Germany were counted.

Raw material inputs of mica were counted in the worksheet „15-MineralsMicaDomestic“. Data were taken from UN-ICSY and from USGS. No hidden flows were counted.

Raw material inputs of other minerals were counted in the worksheet „16-MineralsOtherDomestic“. This concerns only German data taken from official German statistics (production statistics of FSOG). No hidden flows were counted.

Raw material inputs of peat for agricultural, horticultural and other use are reported by the UN Industrial (Commodity) Statistics Yearbook and by USGS. German data were taken from the database of the Wuppertal Institute, originating from official production statistics (Federal Statistical Office Germany - FSOG). They refer to white and black peat for gardening purposes. A universal hidden flow ratio was 0.25 tonnes per tonne used extraction (Douglas and Lawson 1997).

Raw material inputs of pyrite and pyrrhotite were counted in the worksheet „20-OresPyritePyrrhotite Domestic“. Data are reported in gross weights by UN-ICSY (1985 to 1992), EMY (1993 to 1995), Statistical Yearbook for Foreign Countries of FSOG (1996-1997), and by USGS. The coefficients for hidden flows in Germany (in tonnes hidden flows per tonne commodity) were between 0.7 and 1.2, only hidden flows for Germany were counted.

A.2.3.5. Ores

This group of domestic raw materials comprises metallic minerals. It is organised in the following worksheets:
01-OresIronDomestic
02-OresCopperDomestic
03-OresZincDomestic
04-OresLeadDomestic
05-OresBauxiteDomestic
06-OresTinDomestic
07-OresTungstenDomestic
08-OresVanadiumDomestic
09-OresManganeseDomestic
10-OresChromiumDomestic
11-OresNickelDomestic
12-OresTitaniumDomestic
13-OresSilverDomestic
14-OresGoldDomestic
15-OresTantalumNiobiumDomestic
16-OresAntimonyDomestic
17-OresCobaltDomestic
18-OresMercuryDomestic
19-OresUraniumDomestic
20-OresSUMMARYDomestic
Worksheet „20-OresSummaryDomestic“ takes up the results of worksheets 1 to 19.

For the accounting of ores a basic convention with respect to used and unused extractions has to be made. In most statistics, the mine production of metallic minerals is given in weight units of the pure metal content. This is of course far from the situation of the raw materials extracted in mines and used for further purification by smelting and refining. It is even far from an intermediate product often produced within the integrated unit of mining and smelting, e.g. metal concentrates. And it may still be inconsistent even with the highest purity of metal achieved at the final stage of manufacturing. In order to overcome the problem of defining at which quality level, i.e. the grade of metal content of the marketed product leaving the primary production sector, metallic minerals are marketed, it was decided in this study to account for the total mass of metallic mineral in its virgin state as the used extraction of the commodity. So, used extractions in that case comprise the metal content plus the ancillary mass of the crude ore. They are counted by multiplying the metal content in tonnes with 100 divided by the metal grade in %. Hidden flows, or unused extractions, in that case are additional overburden or rock removed to extract the crude ore.

Raw material inputs of iron ores were counted in the worksheet „01-OresIronDomestic“. Data are reported in actual weights by UN-ICSY (1985 to 1992), EMY (1993 to 1995), Statistical Yearbook for Foreign Countries of FSOG (1996-1997), and USGS. German data were replaced by numbers from official German statistics (production statistics of FSOG, mining statistics of the mining authorities of the Federal States, annual reports of the German Federal Institution of Geosciences and Raw Materials). Data for Austria were replaced by the database of the Institute for Interdisciplinary Research and Continuing Education in Vienna (IFF). A universal hidden flow coefficient of 1.38 (in tonnes hidden flows per tonne commodity) was used refering to the situation in Brazil and Canada (Merten et al. 1995).

Raw material inputs of copper ores were counted in the worksheet „02-OresCopperDomestic“. Data are reported in metal contents by UN-ICSY (1985 to 1992), EMY (1993 to 1995), Statistical Yearbook for Foreign Countries of FSOG (1996-1997), and by USGS. Copper grades of ores (in %) were taken from the database of the World Resources Institute (WRI - personal communication, based on publications of the U.S. Bureau of Mines). They were available for Spain, Portugal, Sweden and Finland representing between 88% and 100% of the total EU-15 metal contents. For other member states the average global grades of copper ores were applied. To account for hidden flows of copper ores the following informations were used (also from WRI):
stripping ratio (open-pit) in tonnes overburden per tonne usable extraction
open pit in % of total copper mining
These two parameters were available for Spain and Sweden representing between 74% and 94% of total used extractions in EU-15. No such hidden flows were counted for other member states. For underground mining a minimum rucksack ratio of 0.1 tonnes unused extraction per tonne used extraction was assumed for all member states of EU-15. No hidden flows were counted for the UK.

Raw material inputs of zinc ores were counted in the worksheet „03-OresZincDomestic“. Data are reported in metal contents by UN-ICSY (1985 to 1992), EMY (1993 to 1995), Statistical Yearbook for Foreign Countries of FSOG (1996-1997), and by USGS. Zinc grades of ores (in %) were taken from EMY and from a publication of the U.S. Bureau of Mines (BOM 1993). To account for hidden flows of zinc ores in Germany official data from the mining statistics of the mining authorities of the Federal States were used. For other EU member states a minimum rucksack ratio of 0.1 tonnes unused extraction per tonne used extraction was assumed.

Raw material inputs of lead ores were counted in the worksheet „04-OresLeadDomestic“. Data are reported in metal contents by UN-ICSY (1985 to 1992), EMY (1993 to 1995), Statistical Yearbook for Foreign Countries of FSOG (1996-1997), and by USGS. Lead grades of ores (in %) were taken from EMY and from a publication of the U.S. Bureau of Mines (BOM 1993). To account for hidden flows of lead ores in Germany official data from the mining statistics of the mining authorities of the Federal States were used. For other EU member states a minimum rucksack ratio of 0.1 tonnes unused extraction per tonne used extraction was assumed. For the UK a hidden flow coefficient of 31 was used (Douglas and Lawson 2001).

Raw material inputs of aluminium ores (bauxite) were counted in the worksheet „05-OresBauxiteDomestic“. Data are reported in gross weights of crude ore mined by UN-ICSY (1985 to 1992), EMY (1993 to 1995), Statistical Yearbook for Foreign Countries of FSOG (1996-1997), and by USGS. German data were taken from official German statistics (production statistics of FSOG, mining statistics of the mining authorities of the Federal States, annual reports of the German Federal Institution of Geosciences and Raw Materials). Hidden flow coefficients (in tonnes overburden per tonne bauxite) were available specifically for Greece (Rohn et al. 1995) and for the global average (Adriaanse et al. 1997) which was used for other EU member states.

Raw material inputs of tin ores were counted in the worksheet „06-OresTinDomestic“. Data are reported in metal contents by UN-ICSY (1985 to 1992), EMY (1993 to 1995), Statistical Yearbook for Foreign Countries of FSOG (1996-1997), and by USGS. Tin grades of ores (in

%) were taken from Young (1993) for a global average and for the UK from a publication of the U.S. Bureau of Mines (BOM 1986). A minimum rucksack ratio of 0.1 tonnes unused extraction per tonne used extraction was assumed to account for hidden flows.

Raw material inputs of tungsten ores were counted in the worksheet „07-OresTungstenDomestic“. Data are reported in metal contents by UN-ICSY (1985 to 1992), EMY (1993 to 1995), and USGS. Tungsten grades of ores (in %) were taken for Austria, France, Portugal, Spain, Sweden and the UK from a publication of the U.S. Bureau of Mines (BOM 1985) and from Gocht (1985) for a global average. A minimum rucksack ratio of 0.1 tonnes unused extraction per tonne used extraction was assumed to account for hidden flows.

Raw material inputs of vanadium ores were counted in the worksheet „08-OresVanadiumDomestic“. Data are reported in metal contents by UN-ICSY (1985 to 1992). Finland is the only EU member concerned and data are reported for 1981 to 1985. Vanadium grades of ores (in %) were taken from Gocht (1985) for crude ores in South Africa. A minimum rucksack ratio of 0.1 tonnes unused extraction per tonne used extraction was assumed to account for hidden flows.

Raw material inputs of manganese ores were counted in the worksheet „09-OresManganeseDomestic“. Data are given in actual weights by UNCTAD for 1985 (Commodity Yearbook), EMY for 1986 to 1995, and by USGS. A minimum rucksack ratio of 0.1 tonnes unused extraction per tonne used extraction was assumed to account for hidden flows.

Raw material inputs of chromium ores were counted in the worksheet „10-OresChromiumDomestic“. Data are reported in metal contents by UN-ICSY (1985 to 1992) and in gross weights by EMY (1986 to 1995) and by USGS. A minimum rucksack ratio of 0.1 tonnes unused extraction per tonne used extraction was assumed to account for hidden flows.

Raw material inputs of nickel ores were counted in the worksheet „11-OresNickelDomestic“. Data are reported in metal contents by UN-ICSY (1985 to 1992), and EMY (1993 to 1995), Statistical Yearbook for Foreign Countries of FSOG (1996-1997). Metal grades of ores (in %) were taken for Finland and Greece from a publication of the U.S. Bureau of Mines (BOM 1984) and from Young (1993) for a global average. A minimum rucksack ratio of 0.1 tonnes unused extraction per tonne used extraction was assumed to account for hidden flows.

Raw material inputs of titanium ores were counted in the worksheet „12-OresTitaniumDomestic“. Data are reported in gross weights of ilmenite concentrates by UN-ICSY (1985 to 1992), EMY (1993 to 1995), and by USGS. According to EMY at least 36% titanium are found in concentrates from ilmenite. Nickel grades of ores (in %) were taken for Finland and Italy from a publication of the U.S. Bureau of Mines (BOM 1986) and from Gocht (1985) for a global average of titanium in ilmenite sands. A minimum rucksack ratio of 0.1 tonnes unused extraction per tonne used extraction was assumed to account for hidden flows.

Raw material inputs of silver ores were counted in the worksheet „13-OresSilverDomestic“. Data are reported in metal contents by UN-ICSY (1985 to 1992), EMY (1993 to 1995), Statistical Yearbook for Foreign Countries of FSOG (1996-1997), and by USGS. Silver grades of ores (in %) were taken for Finland, France, Italy, Spain and Sweden from a publication of the U.S. Bureau of Mines (BOM 1986) and from Wilmouth et al. (1991) for a global average. No hidden flows were accounted for because silver is mostly a by-product of other mining in European countries.

Raw material inputs of gold ores were counted in the worksheet „14-OresGoldDomestic". Data are reported in metal contents by UN-ICSY (1985 to 1992), EMY (1993 to 1995), Statistical Yearbook for Foreign Countries of FSOG (1996-1997), and by USGS. Gold grades of ores (in %) were taken from Young (1993) for a global average. A minimum rucksack ratio of 0.1 tonnes unused extraction per tonne used extraction was assumed to account for hidden flows.

Raw material inputs of tantalum and niobium ores were counted in the worksheet „15-OresTantalumNiobiumDomestic". Data are reported in gross weights of concentrates by UN-ICSY (1985 to 1992), and by USGS. No hidden flows were counted.

Raw material inputs of antimony ores were counted in the worksheet „16-OresAntimonyDomestic". Data are reported in metal contents by UN-ICSY (1985 to 1992), and by USGS as antimony oxides in gross weight. Antimony grades of ores (in %) were taken from Gocht (1985) for the average in rich, sulfudic ores. A minimum rucksack ratio of 0.1 tonnes unused extraction per tonne used extraction was assumed to account for hidden flows.

Raw material inputs of cobalt ores were counted in the worksheet „17-OresCobaltDomestic". Data are reported in metal contents of ores and concentrates by UN-ICSY (1985 to 1992). No hidden flows were counted.

Raw material inputs of mercury ores were counted in the worksheet „18-OresMercuryDomestic". Data are reported in metal contents recoverd from ores and concentrates by UN-ICSY (1985 to 1992), and by USGS. Mercury grades of ores (in %) were taken from Wilmouth et al. (1991) for a global average. A minimum rucksack ratio of 0.1 tonnes unused extraction per tonne used extraction was assumed to account for hidden flows.

Raw material inputs of uranium ores were counted in the worksheet „19-OresUraniumDomestic". Data are reported in metal contents of ores and concentrates by UN-ICSY (1985 to 1992), and by USGS. German data were taken from official German statistics (mining statistics of the mining authorities of the Federal States). Uranium grades of ores (in %) were taken from Manstein (1995) for a global average. Rucksack ratios of 1.9 tonnes unused extraction per tonne used extraction were used for underground mining and 30 t/t for open-pit mining (Manstein 1995, open-pit was attributed to the former GDR) to account for hidden flows.

A.2.4. Foreign material flows

The accounting of foreign material input flows (imports) as classified commodities and their hidden flows was described in great detail in the first study on TMR of EU-15 for the EEA (Bringezu and Schütz 2001b). This basic methodology was not changed so that we refer here to the EEA technical report No. 56 on any issue related to the accounting of imported commodities and their hidden flows in general.

In the present study the focus with regard to foreign flows was:

- to extend the existing import database to a time series for EU-15 from 1980 to 1997 (before EU-15 data from 1995 to 1997 were available only), and
- to add exports.

Foreign trade data were organised as shown in FIGURE A.26.

Figure A.26: Overview of files, workbooks or worksheets for imports and exports of the EU.

First order	Second order	Third order
02-Foreign Material Flows		
	01-EUwithUpscaling	
	02-MS01to99-76to97	
	03-ImEx-Summary	
		ImEx-Summary-EUandMS-TotalExtra
		SUMMARY ImportsEU15

File
Workbook or sheet

A.2.4.1. Extra-EU trade

File „01-EUwithUpscaling“ contains extra-EU import and export data for the accession countries to the EU from 1980 to 1997 for the first year these data were reported in foreign trade statistics of Eurostat, these were: Greece 1981, Portugal and Spain 1986, Germany 1990 and 1991 (to account for West Germany 1990 and re-united Germany 1991), Austria, Finland and Sweden 1995. Furthermore, the file contains the original extra-EU trade data from 1976 to 1997 of the EEC respectively EU-15 imports and exports. Based on these original data the time series of EU-15 imports and exports were estimated as follows from the example of the accession of Greece in 1981:

- extra-EU import and export data in metric tonnes for Greece in 1981 were listed in the workbook „Imports7697“ in the worksheet „Greece81“ on the 2-digit level (chapters) of the Nimexe (1976-1987) or HS-CN (1988-1997) classification systems,
- in a next column the share of Greek imports or exports of total EU trade in 1981 was calculated, for additional information it was also expressed as % values in the next column,
- in the worksheet „Extra-EU15“ the estimated time series of EU-15 from 1976 to 1997 were calculated, in our example by adding to the value of the EEC data 1976 to 1980 (in the worksheet „Extra-EC“ the result of the multiplication of the EC-figure with the Greek share in EU 1981.

The resulting time series of extra EU-15 imports and exports from 1976 to 1997 on the 2-digit level of the Nimexe or HS-CN classification systems are found in the workbooks „Imports7697“ and „Exports7697“, each in the worksheets „Extra-EU15“. So, the outcome was, that the imports and exports of the EU-15 were available for each of the 15 Member States from 1976 to 1997.

A.2.4.2. Extra- and Intra-EU trade

In the second file „02-MS01to99-76to97“ the imports and exports of all 15 Member States 1976 to 1997, differentiated by extra-EU and extra- plus intra-EU trade (which is simply the total foreign commodity trade of individual countries equal to extra-EU trade for EU-15 as a whole), are estimated based on data available from foreign trade statistics of Eurostat at the 2-digit level of Nimexe and HS-CN classifications. This procedure is described, again for the example of Greece joining the EU in 1981:
The workbook „Greece.xls“ is split into the worksheets:
Intra+Extra Imports
Intra+Extra Exports
Intra-EC Import
Extra-EC Import
Intra-EC Export
Extra-EC Export

Worksheets Intra-EC Import and Intra-EC Export contain the original data of Greek imports and exports from 1981 to 1997 in metric tonnes.

Worksheets Extra-EC Import and Extra-EC Export contain the original data of Greek imports and exports from 1981 to 1997 plus the estimated data 1976 to 1980 as described before under file „01-EUwithUpscaling“. Furthermore, these worksheets contain tables with the results of the calculation of Intra+Extra-trade divided by Extra-trade.

Worksheets Intra+Extra Imports and Intra+Extra Exports contain the total foreign trade of Greece from 1976 to 1997 based on original and estimated values as follows: original data for intra plus extra trade are summed up from the respective worksheets for 1981 to 1997. The estimated extra EU-data from 1976 to 1980 are multiplied with the coefficients of Intra+Extra-trade divided by Extra-trade to account for the total foreign trade.

Thus, the resulting data are:
- original extra- and intra-EU trade values from 1981 to 1997,
- estimated extra- and extra- plus intra-EU trade data from 1976 to 1980.

For each of these single data sets (in the six worksheets) aggregations with respect to main material categories are made as follows:
1. Sorting by chapters (2-digit classification levels) to sectors and/or materials
- Nutrition
- Minerals
- Mineral fuels
- Chemicals
- Plastics
- Rubber
- Biotic materials
- Textiles
- Mineral products
- Metal products
- Other products

2. Sorting of raw materials by type:
- Fuels
- Ores
- Minerals
- Biomass
- Products

3. Sorting of raw materials and products by type:
- Fuels
- Ores
- Minerals
- Biomass
- Products

The difference between sorting of type 2 and type 3 is, for example, that fossil fuels of type 2 comprise only raw materials as under domestic raw material extraction, i.e. coal, crude oil and natural gas, whereas type 3 comprises in addition products like coke, diesel and town gas. The aggregations are made according to the listings in the annexes of the Eurostat Methodological Guide.

A.2.4.3. Summary of imports and exports

Import and export data are summarised and partly extended in two workbooks:
- ImEx-Summary-EUandMS-TotalExtra
- SUMMARY ImportsEU15

Workbook ImEx-Summary-EUandMS-TotalExtra summarises the data for EU-15 and Member States sorted by types 2 and 3 as described before. It is, therefore, split into the worksheets:
- Total Imports RawSort
- Total Imports RawProdSort
- Extra Imports RawSort
- Extra Imports RawProdSort
- Total Exports RawSort
- Total Exports RawProdSort
- Extra Exports RawSort
- Extra Exports RawProdSort

Data for imported commodities and their hidden flows of the EU, along with some other information, are summarised under the file „Summary“ in the workbook SUMMARY ImportsEU15. The structure of this workbook has been described in detail in the EEA technical report No. 56 in chapter 3.19. In addition to this the workbook SUMMARY ImportsEU15 here contains the additional estimates of imports to EU-15 from 1976 to 1994 (data from 1995 to 1997 were already available before) as well as estimates of their hidden flows resultimg in TMR time series for EU-15 from 1980 to 1997. These data are found in the worksheet „Overview“.

The worksheet „Overview“ starts with a table of imports of EU-15 by chapters (2-digit level) of the foreign trade classification systems. In parallel columns to this table the hidden or unused flows of EU-imports from 1995 to 1997 as worked out in the EEA technical report No. 56 are aggregated. In addition the principle type of hidden flow, i.e. abiotic material, biotic material or soil erosion, is listed in another column.

Below this table another equally structured table by chapters shows the calculated hidden flow coefficients obtained by dividing hidden flows by commodity flows for 1995 to 1997. The chapter average coefficients for 1995 to 1997 are used to estimate the hidden flows of EU-15 imports from 1980 to 1994. This is done in a third table by multiplying the commodity imports of table 1 with the hidden flow coefficients of table 2.

Finally, beneath table 3, the unused or hidden or indirect flows of EU-15 imports from 1980 to 1997 are summarised by sorting of types 2 and 3 as described before.

The overall result of this procedure is a time series of the total material requirement associated with foreign resources (imports) of the EU-15 from 1980 to 1997.

A.2.5. Domestic material outputs to the environment

The accounting for domestic material outputs to the environment by the EU-15 is organised in four files which will be described in detail in the following as shown in FIGURE A.27.

- 01-Emissions to air
- 02-Emissions to water
- 03-Waste landfilled
- 04-Dissipative flows

FIGURE A.27: Basic data files, workbooks and worksheets and their interlinkages for the accounting of material output flows to the environment of EU-15.

First order	Second order	Third order	Fourth order
03-Outputs			
	01-Emissions to air		
		00-raw data	
		01-Final data	
			01-CO2
			02-CH4
			03-N2O
			04-HFC,PFC,SF6
			05-CO
			06-NH3
			07-NMVOC
			08-NOX
			09-SO2
			10-Emissions to air Summary
	02-Emissions to water		
		Emissions to water	
	03-Waste landfilled		
		Waste landfilled	
	04-Dissipative flows		
		00-raw data	
		01-Fertilizers.xls	
		02-Manure	
		03-Pesticides.xls	
		04-seeds	
		05-Other agricultural	
		06-Other dissipative	
		07-Dissipative flows Summary	

File

Workbook or sheet

A.2.5.1. Emissions to air

Emissions to air data are organised in the following files:
- 00-raw data
- 01-Final data
  - 01-CO2
  - 02-CH4
  - 03-N2O
  - 04-HFC,PFC,SF6
  - 05-CO
  - 06-NH3
  - 07-NMVOC
  - 08-NOX
  - 09-SO2
  - 10-Emissions to air Summary

File 00-raw data contains basic data from EEA, Eurostat and Matthews et al. 2000.

Worksheets 01 to 09 in file 01-Final data contain the respective total anthropogenic emission data from EEA or Eurostat for EU-15 and Member States from 1980 to 1998. The original emission data were modified according to the requirements of the material balancing methodology as follows (to avoid double-counting of outputs):
- Methane emissions from landfills were excluded
- N_2O emissions from fertilisers and landfills were excluded

Workbook 10- Emissions to air Summary combines the information from worksheets 1 to 9, compares them with original national databasis, creates a representative new database, and aggregates the latter emissions to air in its first worksheet „Summary".

In addition, molecular oxygen related to emissions is calculated in worksheet „Overview" for further use as a balancing item (see chapter A.2.6).

A.2.5.2. Emissions to water

Emissions to water are summarised in the workbook:
- Emissions to water

Only data available from national databases were used. These national data were:
- For Austria from 1980 to 1996 (Matthews et al. 2000):
  - Organic carbon in waste water
  - Nitrogen in waste water
  - Phosphorus in waste water
  - AOX in waste water
- For Germany (West-Germany until 1990) from 1980 to 1996 (Matthews et al. 2000):
  - N
  - P
  - Others

- For the Netherlands from 1980 to 1996 (Matthews et al. 2000):
  - N
  - P
  - Others (Chloride)
- For Finland 1987, 1992, 1997 (Muukkonen 2000):
  - Total emissions to water: the average of the three years reported was used as an estimate for remaining years in between 1987 and 1997.
- For Spain 1990 (Eurostat 1996):
  - sewage sludge dumping at sea
- For the UK 1985, and 1990 to 1997 (DETR 1998 and personal communication):
  - Sewage sludge: Total amount dumped (thousand dry tonnes)
  - Solid industrial waste: Total amount dumped (thousand dry tonnes)
  - Fish waste: Total amount dumped dry tonnes)
  - Oil spills from offshore installations

Note:
- As in Matthews et al. 2000, dredged materials are removed from the output indicator DPO, but they are part of domestic indirect flows (under excavation and dredging) and TDO.

A.2.5.3. Waste landfilled

Data for landfilled waste are gathered in the workbook:
- Waste landfilled

According to the rather sporadic data availability in most Member States the workbook was split into three worksheets:
- Municipal
- Industrial
- Sewage
- Summary

In worksheet „Municipal“ data available from national databases were gathered. These were:
- for Germany (West-Germany until 1990) and the Netherlands from 1980 to 1996 (Matthews et al. 2000)
- for the UK 1995 to 1998 (DETR 1998 and personal communication)
- for Finland 1987, 1992 and 1997 (Muukkonen 2000)
- for other Member States as shown in Figure A.13.

From these original data coefficients in tonnes landfilled waste per capita were calculated (TABLE A.9). Missing coefficients were estimated on the basis of other existing national data or by using a weighted, multi-annual EU-wide average coefficient as shown in table A.9. The distribution of coefficients shows that data prior to 1990 are scarce which led to the decision made for this study to account for material outputs to the environment only from 1990 to 1996. Data for Austria were not available by the differentiation into municipal but for the total amounts of landfilled wastes, they were therefore integrated into this database at the summary level in worksheet „Summary“.

TABLE A.9: Municipal waste landfilled in tonnes per capita.

Coefficients: tonnes per capita																			
Waste landfilled																			
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
EU 15																			
Austria											0.22								
Belgium-Luxembourg											0.06	0.06	0.06	0.06	0.06	0.06	0.06		
Denmark											0.09	0.09	0.09	0.09	0.09	0.09	0.09		
Finland								0.33			0.48	0.45	0.42	0.42	0.42	0.42	0.42	0.43	
France											0.17	0.17	0.17	0.17	0.17	0.17	0.17		
Germany											0.18	0.17	0.16	0.15	0.15	0.15	0.15		
Greece											0.29	0.29	0.29	0.29	0.29	0.29	0.29		
Ireland					0.31						0.31	0.31	0.31	0.31	0.31	0.31	0.31		
Italy											0.40	0.40	0.40	0.40	0.40	0.40	0.40		
Netherla	1.08	1.02	0.96	0.90	0.90	0.90	0.91	0.93	0.94	0.94	0.96	0.89	0.88	0.85	0.79	0.64	0.55		
Portugal											0.29	0.29	0.29	0.29	0.29	0.29	0.29		
Spain											0.30	0.30	0.30	0.30	0.30	0.30	0.30		
Sweden											0.15	0.15	0.15	0.15	0.15	0.15	0.15		
United Kingdom										0.24	0.41	0.41	0.41	0.41	0.41	0.41	0.42	0.44	0.44
West-Germany																			
Weighted averages: annua											0.2939	0.3307	0.2553	0.2513	0.2315	0.2954	0.2885		
% population											32%	42%	59%						
Weighted averages: multi-annual EU-wide													0.2919						
Coefficients for estimates 1990-1996																			

In worksheet „Industrial“ data available from national databases were gathered. These were:

- for Germany (West-Germany until 1990) from 1980 to 1996 (Matthews et al. 2000), further differentiated by commercial and industrial waste and construction waste,
- for the UK 1997 to 1998: construction waste going to landfill in 1997 and 1998 (Indicator D 10 of Quality of Life Counts), commercial and industrial waste landfilled 1998 (DETR),
- for Finland 1987, 1992 and 1997 (Muukkonen 2000) differentiated by: Industry, Agriculture, Construction/demolition,
- for Sweden 1993 : manufacturing industry (Isacsson et al. 2000), construction sector (Bergstedt and Linder 1999).

From these original data coefficients in kg landfilled waste per ECU GDP were calculated (TABLE A.10). Missing coefficients were estimated on the basis of a weighted, multi-annual average coefficient for Finland, Germany and the UK which was applied to all other Member States for 1996 as shown in table A.10. Variations of the coefficients were taken into account by adding to the coefficients starting from 1995 the annual increment for Finland between 1992 to 1997, thus, deriving increasing coefficients from 1995 back to 1990. The distribution of coefficients shows that data prior to 1990 are scarce which led to the decision made for this study to account for material outputs to the environment only from 1990 to 1996. Data for Austria were not available by the differentiation into industrial but for the total amounts of landfilled wastes, they were therefore integrated into this database at the summary level in worksheet „Summary“.

TABLE A.10: Industrial waste landfilled in kg per ECU GDP.

Waste landfilled: national databases: kg per ECU																					
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Increment annual
EU 15																					
Austria																					
Belgium-Luxembourg											0.07	0.07	0.07	0.07	0.06	0.06	0.06					0.002315546
Denmark											0.07	0.07	0.07	0.07	0.06	0.06	0.06					0.002315546
Finland								0.13	0.12	0.11	0.10	0.09	0.08	0.07	0.07	0.07	0.07	0.06				
France											0.07	0.07	0.07	0.07	0.06	0.06	0.06					0.002315546
Germany											0.05	0.05	0.05	0.05	0.04	0.04	0.04					0.002119977
Greece											0.07	0.07	0.07	0.07	0.06	0.06	0.06					0.002315546
Ireland											0.07	0.07	0.07	0.07	0.06	0.06	0.06					0.002315546
Italy											0.07	0.07	0.07	0.07	0.06	0.06	0.06					0.002315546
Netherlands											0.07	0.07	0.07	0.07	0.06	0.06	0.06					0.002315546
Portugal											0.07	0.07	0.07	0.07	0.06	0.06	0.06					0.002315546
Spain											0.07	0.07	0.07	0.07	0.06	0.06	0.06					0.002315546
Sweden											0.07	0.07	0.07	0.07	0.06	0.06	0.06					0.002315546
United Kingdom											0.11	0.11	0.10	0.10	0.10	0.10	0.09	0.09				0.002315546
West-Germany																					
Weighted averages													0.05					0.09				
muli-annual: FIN,UK,D																	0.06					
Finland: original								0.13					0.08					0.06				0.002315546
coefficients for estimates 1990-1996																					
Finland								1.66					1.00					0.85				
Germany											1.04	1.00	0.92	0.91	0.82	0.77	0.75					

In worksheet „Sewage“ data available from national databases were gathered. These were:
- for Germany (West-Germany until 1990) and the Netherlands from 1980 to 1996 (Matthews et al. 2000)
- for the UK 1991 to 1998 (DETR 1998 and personal communication)
- for Finland 1987, 1992 and 1997 (Muukkonen 2000)
- for other Member States as shown in Figure A.13.

These original data were taken over as they were reported, no additional estimates were performed in this study.

In the worksheet „Summary“ data collected from the national databases and estimated for municipal, industrial and sewage waste landfilled as described before are summed up. The Austrian national database (Matthews et al. 2000) is further integrated there. The outcome are time series of reported and estimated total amounts of landfilled waste by the Member States which add up to the EU-15 total from 1990 to 1996.

A.2.5.4. Dissipative flows

Data on dissipative flows are organised in the files and workbooks:
- 00-raw data
- 01-Fertilizers.xls
- 02-Manure
- 03-Pesticides.xls
- 04-seeds
- 05-Other agricultural
- 06-Other dissipative
- 07-Dissipative flows Summary

File 01-Fertilisers.xls contains FAOSTAT data on consumption by the Member States and EU-15 totals from 1980 to 1998 on:
- Nitrogenous Fertilizers
- Phosphate Fertilizers
- Potash Fertilizers
- Total Fertilizer, which is the sum of the three sub-types.

The data for Austria, Germany and the Netherlands were cross-checked with the original databases from 1980 to 1996 (Matthews et al. 2000) and replaced by them which led to the final database of EU-15.

The workbook 02-Manure contains worksheets with data on the livestock populations by types as given in FAOSTAT from 1980 to 2000. Manure coefficients in dry weight per head are found in the worksheet „Coefficients“, they were taken from Meißner 1994 and Matthews et al. 2000. Manure production is calculated by multiplying coefficients with livestock numbers in the worksheet „Summary“. The data for Austria, Germany and the Netherlands were cross-checked with the original databases from 1980 to 1996 (Matthews et al. 2000) and replaced by them which led to the final database of EU-15.

The workbook 03-Pesticides contains worksheets with data on the consumption of pesticides by sub-types of FAOSTAT from 1990 to 1997 (these data were not available prior to 1990). The raw data are aggregated in the worksheet „Summary“ by:

- Insecticides
- Mineral Oils
- Herbicides
- Fungicides, Bactericides and Seed Treatments
- Plant Growth Regulators
- Rodenticides

The data for Austria, Germany and the Netherlands were cross-checked with the original databases from 1980 to 1996 (Matthews et al. 2000) and replaced by them which led to the final database of EU-15.

The workbook 04-seeds contains worksheets with data by Member States on the production of seeds by sub-types of FAOSTAT from 1990 to 1997. The raw data are aggregated in the worksheet „Summary“.

The workbook 05-Other agricultural contains data of other dissipative outputs in agriculture from specific national databases. These are:

- For Austria 1980 to 1996 (Matthews et al. 2000): Other (sewage sludge, seeds, compost, ...) from which the seed data from FAOSTAT were subtracted,
- For Germany 1980 to 1996 (Matthews et al. 2000): Sewage sludge spread on fields, Compost,
- For the Netherlands 1980 to 1996 (Matthews et al. 2000): Sewage sludge spread on fields,
- For the UK 1990 to 1997 (DETR 1998): Sewage sludges on farmland.

These national data are summed up to EU-15 totals in worksheet „Summary“, no further estimates were done.

The workbook 06-Other dissipative contains data of other dissipative outputs from specific national databases. These are:

- For Austria 1980 to 1996 (Matthews et al. 2000): Dissipative Losses from Roads and Tyres, Dissipative Uses (thawing and grit materials),
- For Germany 1980 to 1996 (Matthews et al. 2000): Grit materials, Abrasion (tyres), Accidents with chemicals, Leakages (natural gas), Erosion of infrastructures (roads).

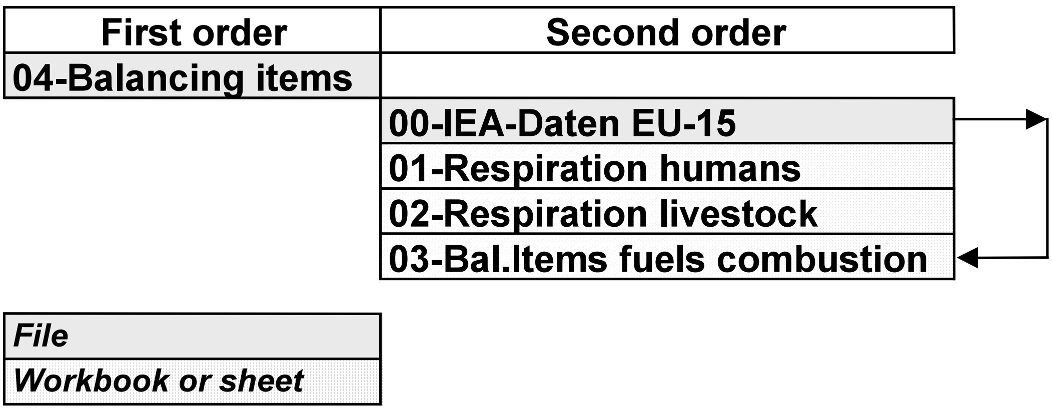
These national data are summed up to EU-15 totals in worksheet „Summary“, no further estimates were done.

The workbook 07-Dissipative flows Summary takes up via automatic links the summary results of workbooks 1 to 6 described before. These data are summarised in a worksheet „Summary categories“ where the data of the six major groups of material outputs were filtered by the 15 Member States and the EU-15 total. Worksheet „Summary totals“ adds up the six categories to the total dissipative use of products and dissipative losses of the 15 Member States and the EU-15 total. The data for Austria, Germany and the Netherlands were cross-checked with the original databases from 1980 to 1996 (Matthews et al. 2000) and replaced by them which led to the final database of EU-15.

A.2.6. Balancing items

Balancing items were introduced by Matthews et al. (2000) and taken up by Eurostat (2000) to improve the accuracy of the overall material flow balance of an economy, and, at the same time, to point out that these material flows are for some reasons not considered as part of the major material flow indicators DPO and TDO. The balancing items cover two major issues, i.e. respiration by humans and livestock (in particular O_2 as input and CO_2 and water vapor as outputs) and, additional to emissions to air recorded in DPO and TDO, emissions of water vapor from the combustion of fuels (originating either from intrinsic water contents of fuels or from their oxidised hydrogen contents) within the economy, as well as the total of molecular oxygen accounted for stochiometrically on the input side to counterbalance the emissions to air as oxidised compounds from fuels combustion on the output side (FIGURE A.28).

FIGURE A.28: Basic data files, workbooks or worksheets and their interlinkages for the accounting of balancing items needed to create the total material flow balance of the EU.



A.2.6.1. Respiration

Respiration is accounted in the workbooks 01-Respiration humans and 02-Respiration livestock using coefficients from Matthews et al. 2000. Human respiration was estimated by (tonnes per capita per year):

- 0,30 CO_2
- 0,25 O_2
- 0,35 H_2O (water vapor)

Livestock respiration was estimated by per head coefficients:

	kgCO2 per day	t CO2 per year	t H2O per year	t O2 per year
Cattle	8	2.920	3.376	2.449
Sheep	0.65	0.237	0.274	0.199
Horses	6	2.190	2.532	1.836
Pigs	0.825	0.301	0.348	0.253
Chickens	0.035	0.013	0.015	0.011
Ducks	*0.035*	*0.013*	*0.015*	*0.011*
Geese	*0.035*	*0.013*	*0.015*	*0.011*
Turkeys	*0.035*	*0.013*	*0.015*	*0.011*

A.2.6.2. Combustion of fuels

Basic energy consumption data used to account for the balancing items of fuels combsution by Member States are found under the file 00-IEA-Daten EU-15, as well as coefficients needed to account for these balancing items, and conversion factors needed to obtain the fuels use data fit to the conversion factors. The coefficients and conversion factors come from the databasis of the Wuppertal Institute developed during work on the physical input-output table for Western Germany 1990 in cooperation with the Federal Statistical Office Germany.

Workbook 03-Bal.Items fuels combustion contains the calculated balancing items by Member States related to fuels combustion which are:

- Water vapor (H_2O) from H
- Water vapor from H_2O
- corresponding input of oxygen for water vapor from H
- corresponding input of oxygen for CO_2, CO, NO_2, SO_2, N_2O

A.2.7. Indicators

Based on all the data and information gathered so far as described in chapters A.2.1 to A2.6 of this annex, the files and workbooks aggregating the major material flow indicators are constructed as shown in FIGURE A.29.

File 00-general contains the information shown in Table A.11 on the kind of information provided in the workbooks summarising data for the material flow indicators and aggregates.

TABLE A.11: Overview of information available in the indicators summaries:

Indicator or aggregate or material flow	Period	Data available for each of the 15 Member States
TMR	80 to 97	NO
DMI	80 to 97	YES
DPO	90 to 96	YES
TDO	90 to 96	YES
Material balance	90 to 96	YES (but currently not prepared)
NAS	90 to 96	YES
DMC	80 to 97	YES
PTB commodities	80 to 97	YES
CO_2	90 to 97	YES
SO_2	80 to 97	YES
NOx	80 to 97	YES

FIGURE A.29: Basic data files, workbooks and worksheets and their interlinkages for the accounting of the main material flow indicators of the EU.

First order	Second order	Third order
05-Indicators		
	00-General	
		Indicators EU-15
	01-DMI/DMC	
		01-DMI EU15 by MS RAWsort
		02-DMI EU15 by MS PRODsort
		03-DMI EU15 and MS RAWsort
		04-DMI EU15 and MS PRODsort
		05-DMC EU15 by MS RAWsort
		06-DMC EU15 by MS PRODsort
		07-DMC EU15 and MS RAWsort
		08-DMC EU15 and MS PRODsort
		Check-grazing
		DMI-profiles MS
		FINmine.xls
		Grazing-example for D
	02-TMR	
		TMR EU15
	03-DPO/TDO	
		DPO/TDO
	04-Material balance	
		Material balances
		MB-EU15-1996-Mt
		MB-EU15-1996-Mt-word98
		PTB commodities
	05-Summary	
		Summary

File
Workbook or sheet
Word document

A.2.7.1. DMI and DMC

Data are organised in the workbooks:

- 01-DMI EU15 by MS RAWsort
- 02-DMI EU15 by MS PRODsort
- 03-DMI EU15 and MS RAWsort
- 04-DMI EU15 and MS PRODsort
- 05-DMC EU15 by MS RAWsort
- 06-DMC EU15 by MS PRODsort
- 07-DMC EU15 and MS RAWsort

- 08-DMC EU15 and MS PRODsort
- Check-grazing
- DMI-profiles MS
- FINmine.xls
- Grazing-example for D

Workbooks 01 to 08 take up the linked data as described before and aggregates them to derive the material flow indicators DMI and DMC for EU-15 split into the shares of the Member States (by MS) or for EU-15 and the Member States as entire economies (and MS)[30]. Further distinctions concern the sorting of imported and exported commodities by raw material groups (RAWsort) or by raw material plus product groups (PRODsort) as decribed in chapter A.2.4.2. For data analysis and international comparison in the final report only DMI and DMC data from workbooks 04 respectively 08 were used.

Workbook „Check-grazing“ contains in the worksheet „Comparison table“ a comparison of yields applied to account for the biomass taken up by grazing of livestock on permanent pastures and yields reported by FAOSTAT for green fodder like:

- Alfalfa for Forage+Silag
- Clover for Forage+Silage
- Forage Products Nes
- Grasses Nes,Forage+Silag
- Rye Grass,Forage+Silage

This comparison was done as a kind of first approach to figure out whether the average German yields used to estimate biomass intake by grazing were reasonable or not for the other Member States. This comparison showed that the German yields rather tend to underestimate biomass from grazing in other Member States. Therefore, the EU-15 total domestic biomass input of this type may be rather seen as a minimum estimate.

Workbook „DMI-profiles MS“ contains profiles by main material groups and categories of DMI of the EU-15 and the Member States from 1980 to 1997, as well as comparisons with original national databases.

Worksheet „FINmine.xls“ contains original data on domestic mine production of minerals in Finland provided by Ilmo Mäenpää, Thule Institute at Oulu, Finland.

Worksheet „Grazing-example for D“ contains the information about the derivation of German yields for the accounting of biomass taken up by grazing of livestock on permanent pastures. This calculation procedure was done by the authors of this study and confirmed by the German Ministry of Nutrition, Agriculture and Forestry (personal communication by email). The German yields had been used in the present study to account for corresponding domestic biomass inputs in other EU Member States except Austria and the UK which had developed their own specific national databases (see also chapter A.2.3.1.1).

[30] DMC of EU-15 by Member States and DMC of EU-15 and Member States should be the same, because in the case of DMC the intra-EU trade (imports and exports) of the Member States is netted out. Differences occurring here in the study are due to differences in the statistical database showing up by different kinds of data aggregations. For EU-15 by MS the total extra EU-15 foreign trade was obtained by summing up the extra-EU trade values of the 15 Member States. For EU-15 and MS the extra EC- foreign trade data were downloaded from the database and supplemented with the extra-EC trade values of the Member States not represented in the EC-total, e.g. Greece in 1980. The difference between the two approaches is indeed very small for DMC of the EU-15 ranging between minus 0.01% to plus 0.5% from 1980 to 1997.

Shortly before writing the present final report the authors had finished a study on Total Material Resource Flows of the United Kingdom for DETR and ONS (Bringezu and Schütz 2001c). The refined material flow data for the UK resulting from this study were integrated into the EU database underneath line 379 of the workbook 04 and line 380 of the workbook 08.

A.2.7.2. TMR

The workbook „TMR EU15“ is structured by main material flow aggregates:
- Domestic DMI
- Domestic hidden flows
- Domestic TMR
- Foreign DMI
- Foreign hidden flows
- Foreign TMR

These aggregates are differentiated by material groups:
- Fossils
- Minerals
- Biomass
- Products
- Excavation
- Erosion

These material flow categories are summed up to the Total Material Requirement of the EU-15 expressed in kilotonnes, tonnes per capita and kg per ECU GDP.

Shortly before writing the present final report the authors had finished a study on Total Material Resource Flows of the United Kingdom for DETR and ONS (Bringezu and Schütz 2001c). The refined material flow data for the UK resulting from this study were integrated into the EU database underneath line 144 of the workbook „TMR EU15“.

A.2.7.3. DPO and TDO

The workbook „DPO/TDO“ is organised in 2 worksheets:
- EU-15 Materials
- EU-15 by MS

Worksheet EU-15 Materials takes up the linked data of major material output categories as described before and aggregates them to derive the material flow indicators DPO and TDO for EU-15:
- CO_2
- Other emissions to air
- Emissions to water
- Waste landfilled
- Dissipative use of products and dissipative losses

These categories sum up to DPO.
- Unused extraction
- Excavation
- Unused biomass
- Erosion

These categories and DPO result in TDO.

Corresponding data for the EU and the 15 Member States are summarised in the worksheet „EU-15 by MS“.

A.2.7.4. Material Balance

The file 04-Material balance contains the items:
- Material balances (Workbook)
- MB-EU15-1996-Mt (Word document)
- MB-EU15-1996-Mt-word98 (Word document)
- PTB commodities (Workbook)

Workbook „Material balance“ takes up the linked data for constructing the overview material flow balance of the EU from 1990 to 1996. It also contains corresponding data for the Member States, in particular the data for Net Additions to Stock (NAS, in the worksheet of the same name).

Word documents MB-EU15-1996-Mt (Word 5, which is used instead of Word 98 for technical reasons of constructing the graph) and MB-EU15-1996-Mt-word98 (Word 98 for final use as graph in the report) contain the graphs of the Material Blance of the EU-15 in 1996.

Workbook „PTB commodities“ takes up the linked data for the accounting of the physical trace balances for commodities of EU-15 and the Member States.

A.2.7.5. Summary

Workbook „Summary“ has two worksheets:
- Summary EU-15
- Data links

Worksheet „Data links“ takes up by automatic links the summary tables of major material flow aggregates and indicators of domestic inputs, imports and exports, and hidden flows for the EU-15 and the Member States as far as data are available for the latter.

Worksheet „Summary EU-15“ aggregates this information for the EU-15 totals 1980 to 1997 and adds by automatic linkages the EU-15 total data for material outputs to the environment and material balances. It further contains the data for population and GDP.

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