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Interim Report **IR-02-057**

Material Flows and Economic Development
Material Flow Analysis of the Hungarian Economy

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February, 2003

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List of abbreviations

DMC	Domestic Material Consumption
DMI	Direct Material Input
EU	European Union
FAO	Food and Agricultural Organization
GDP	Gross Domestic Product
MFA	Material Flow Analyses
MI	Material Input, Material Intensity
MIPS	Material Intensity per Service Unit
NAS	Net Addition to Stocks
OECD	Organization for Economic Cooperation and Development
PIOT	Physical Input Output Table
PTB	Physical Trade Balance
TMC	Total Material Consumption
TMI	Total Material Input
TMR	Total Material Requirement
UN	United Nations

Abstract

This report presents preliminary results of a material flow analysis (MFA) of the Hungarian Economy for to years 1993-1997. Material flow based indicators like Direct Material Input (DMI) and Total Material Requirement (TMR) are used as environmental sustainability indicators. The analysis of the structure of the material flows shows the share of domestic and foreign components and the shares of several material categories. The time series demonstrates that only a relative decoupling of material flows and economic activity has taken place during the last years. Although a decrease of the indicators per GDP during the last years of the analyzed period could be observed both material flows in absolute numbers and material flows per capita have increased. Material intensity of the Hungarian economy in terms of material requirement per economic output is higher–and vice versa material efficiency is lower–compared to Western Industrialized Countries. In contrast material inputs per capita are lower than in most Western Countries. The paper closes with a methodological discussion of the applied indicators and policy and research implications.

Keywords: Total Material Requirement (TMR), Material Flow Analyses (MFA), Societal Metabolism, Industrial Metabolism, Dematerialization, Eco-efficiency, Environmental Accounting, Sustainability Indicators, Rebound Effect, Factor X

Acknowledgments

We want to thank the following persons for their help and advice: Günther Fischer, János Gács and Vladimir Benacek at IIASA, Friedrich Hinterberger and Stefan Giljum at the Sustainable Europe Research Institute (SERI, Vienna), Christopher Manstein at Verein Faktor 4+ (Klagenfurt, Austria), Marina-Fischer-Kowalski, Helga Weisz, Nina Eisenmenger, Heinz Schandl, Christof Amann and Karlheinz Erb at the Institute for Interdisciplinary Studies of Austrian Universities (Vienna), Petra Oswald at the Austrian Institute for Applied Ecology (Vienna), Harald Wilfing at the Institute for Anthropology at the University of Vienna, Helmut Schütz at the Wuppertal Institute for Climate, Environment and Energy (Wuppertal, Germany), Jerzy Sleszynski at the Ecological Economics Centre at Warsaw University, Milan Scasny at the Charles University Environment Center (Prague), Ilmo Mäenpää at the Thule Institute at the University of Oulu (Finland), Jukka, Muukkonen at Statistics Finland, Aldo Femia at the Instituto nazionale di statistica (ISTAT, Rome) and all the others who discussed this paper with us and helped us with essential information.

We want to express our thanks to Aviott John, Eduard Löser, Wilson Tan Ho and Natalia Ovtchinnikova from the IIASA library for their valuable help in finding literature and data. Many thanks go also to Margaret Traber who organized the Young Summer Scientists Program at IIASA, which enabled the co-operation for this article.

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Material Flows and Economic Development - Material Flow Analysis of the Hungarian Economy

Mark Hammer and Klaus Hubacek

1. Introduction

The aim of this study is to assess the path of the Hungarian economy towards sustainable development. As indicators for ecological sustainability material flow based indicators will be used. This paper presents results of a material flow analysis of the Hungarian economy for the years 1993-1997. The results will be compared with similar studies undertaken for other countries (Adriaanse *et al.* 1997, Bringezu and Schütz 2001a, Mündl *et al.* 1999).

The research is guided by the following questions and interests:

- How efficient are resources used, above all in comparison to western European countries? Given existing inefficiencies at the plant, sectoral, and macro-economic level in Eastern Europe countries it was expected that material indicators per GDP are higher in Hungary compared to western industrialised countries. This would mean that 'material efficiency' is lower and resource intensity of the economies is higher than in western countries.
- How large is per capita material consumption compared to other industrialised countries? Given the economic performance and development path of eastern European economies of the last decades and their lower levels of living standard and consumption, it was expected that material indicators per capita are lower than in western countries.
- How did efficiency and per capita consumption develop during the last years? Observing the changes eastern European economies have made during the last decade it is to be expected that both material efficiency and material consumption per capita have increased within the last years.

The following study tries to answer these questions which are considered as important questions for ecological sustainability in the context of the future accession of Hungary to the European Union. It is believed that it is an important task on the way to sustainable development to increase the standard of living without considerably increasing material and energy consumption.

In the next chapter a short overview will be presented of the importance of the material basis of industrial economies and its historic development during the last century. Chapter 3 describes the basic concepts that build the theoretical frame for the analysis. Chapter 4 summarises statements on the importance of dematerialisation for the political agenda. Chapter 5 presents the methodology of material flow accounting that has been used for the empirical case study. In chapter 6 the main purposes of material flow analysis and its application to decoupling and international trade issues are described. Chapter 7 presents the empirical results of the material flow analysis for Hungary. Chapter 8 discusses possible future methodological and empirical developments and applications of material flow analysis and chapter 9 points out the characteristics of an environmental and ecological economic policy aiming for dematerialisation. In appendix 1 a detailed description of the empirical calculations is given and appendix 2 contains summary tables of the empirical results.

2. Relevance of material flows

2.1 Historical development

Economic activities are based on the extraction and transformation of natural resources. During the last century the material basis of industrial economies has grown. And with it grew the amount of wastes, emissions, and environmental problems related to resource extraction and waste disposal.

During the last 150 years many technical innovations in production processes or transport technology or several socio-economic developments–mass production and consumption, subsidized resource extraction, invention of new materials–had increased overall material consumption (Gardner and Sampat 1999, pp. 42).

Total global marketable material production increased 2.4-fold between 1960 and 1995. Since 1960 global plastic production increased six-fold and global cement production eight-fold. As more than 100,000 new chemical compounds have been developed since the 1930s, production of synthetic chemicals in the United States grew 1,000-fold during the last 60 years. Worldwide aluminum production increased 3,000-fold during this century. Strengthened recycling efforts for certain materials–in the mid 1990s in industrialized countries about 40% of the paper and cardboard and about 50% of the glass have been recycled–did not lead to an decrease in material consumption (ibid. pp. 44). Furthermore recycling rates at a national level do nowhere exceed 5% of direct material input (Fischer-Kowalski and Hüttler, 1999, p. 120).

Most materials that enter economic production and consumption end up in incinerators or landfills in a short period of time (Gardner and Sampat 1999, p. 42). For example in Germany, about 80% of the resources extracted are released to the environment within the same year (see Stahmer *et al.* 1996, 1997).

2.2 Environmental problems as a consequence of material flows

Extraction of resources as well as waste disposal and emissions can be related to environmental and health problems. Resource extraction is responsible for a loss of habitat for species and a weakening of ecosystem services like erosion control. For the extraction of minerals toxic chemicals are used and often released directly into the environment. Mines can still leach pollutants many years after they were closed and cleaning up those sites will require considerable financial means. Many new synthetic chemicals can lead to unexpected consequences in any part of the world far away from the emission site, as these chemicals are ubiquitous and long-lived. Information on the health effects of chemicals is often not available. Human induce material flows also influence large-scale geo-chemical cycles. The emission of CO_2 due to the combustion of fossil fuels has global impacts and humans are the planet's leading producers of fixed nitrogen, leading to algae blooms and changes in biological diversity of grasslands (Gardner and Sampat 1999, pp. 46).

Fischer-Kowalski and Hüttler (1999, pp. 119) add further arguments for the relevance of material flows. One is the exhaustion of resources, which has been of interest since long time and is also stressed in discussions on the material intensive development model of western capitalism. Material flows are not only problematic if toxic materials are concerned. The sheer amount of flows of non-toxic materials can also cause mayor environmental problems (like for example, global climate effects due to CO_2 emissions, as already mentioned by Ayres and Kneese 1969). Ayres (1994, p. 6) marks today's industrial systems as unsustainable as their material cycles are not closed–unlike in ecological systems. All materials that are lost in form of waste and dissipative losses lead to new extraction activities to replace these losses.

3. Basic concepts

3.1 Sustainable development

The concept of sustainable development aims to link issues of economic, environmental, social and institutional developments. These areas are seen as interdependent and therefore understanding of development problems and their solutions cannot be found in only one of these domains but only in an integrated view of all areas by recognising complex interrelations between them. The main starting point in the development of the concept was the idea of linking environmental and developmental questions. These basic concepts have mainly been developed by the World Commission on Environment and Development (WCED 1987) and the UN Conference on Environment and Development (UNCED) held in Rio in 1992. In this study the terms 'sustainable development' and 'sustainability' are used synonymously, (e.g., see Ott, 2001).

3.2 Environmental indicators

(Environmental) indicators help to measure changes and progress in development. They have the following functions: they enable a state analysis, they contribute to the development of policies and they help to monitor enforcement of political targets. Indicators can fulfil three main purposes: (1) Analysis: Indicators should be based on world-wide recognised methodologies and valid data. (2) Political guidance: Indicators should provide links to players, causes and instruments. (3) Communication: Indicators should be vivid and easily understandable. There will not be one single optimal set or system of indicators, but different mutually reinforcing systems. All indicator systems are unavoidably based on value decision (for example by choosing 'relevant' phenomena or by setting target values) (Spangenberg *et al.* 1999, pp. 24).

The *European Environment Agency (EEA)* uses a typology of four groups of environmental indicators (Smeets and Weterings 1999): descriptive, performance, efficiency, and total welfare. Descriptive indicators (type A) describe the actual situation of the environmental status. Performance indicators (type B) compare this actual situation with reference conditions and are used as a 'distance to target' assessment. Efficiency indicators (type C) relate environmental pressures to human activities. Total welfare indicators (type D) can be used as a measure of total sustainability.

Descriptive indicators are further separated by the so-called DPSIR framework (Driving forces, Pressure, State, Impact, Response). Driving forces can be overall levels of consumption and production patterns. Pressure indicators show to which extent resources or land are used. State indicators describe the quality of the environmental system (for example, fish stocks). Impact indicators illustrate the effects of environmental changes, for example, on health conditions. Response indicators explain the reactions of the social system to these changes, for example, increasing recycling efforts.

The EEA has suggested a set of environmental headline indicators in which the Total Material Requirement (TMR) is recommended as a measure of resource use (EEA 1999c, p. 6, EEA 1999a, p. 49). In the EEA typology of indicators TMR would be a descriptive pressure indicator. If TMR is put into relation to GDP it can be used as an indicator of eco-efficiency (type C) or response indicator (in the sense of improved efficiency). If TMR is compared with targets like Factor 4 or Factor 10 these indicators can also be used as performance indicators (type B). In its *Environmental Assessment Report No 6 – Environmental Signals 2000* – the EEA has described the development of the TMR of the European Union (EEA 2000, chapter 16).

An overview of physical indicators for the measurement of environmental sustainability (including approaches based on material flows as well as ones based on land appropriation) is given by Giljum and Hinterberger (2000) and Moffatt *et al.* (2001).

3.3 Eco-efficiency and total material consumption

Eco-efficiency can be considered as an input-output ratio (OECD 1998, p.15) or as de-coupling of resource use and pollution from economic activity or growth (EEA 1999a, p.45). Several indicators are used to describe the eco-efficiency of economic processes and sometimes the same term may be used for different indicators. Material-based eco-efficiency indicators measure the total material input in relation to output in either physical (weight of products) or economic units (GDP). Eurostat (2001, p. 43) uses material efficiency or material productivity synonymous for units of GDP produced by units of materials used. Hüttler *et al.* (1997b, p. 112) distinguish between these two indicators. They too define material productivity as unit of GDP per material input. But they classify material efficiency as the relation of the weight of a product to the weight of the material inputs. Material intensity is in both references characterised as material input per unit GDP.

Table 1: Material efficiency, productivity, and intensity

Source	Definition of terms		
	Material efficiency	Material productivity	Material intensity
Eurostat (2001)	GDP/MI	GDP/MI	MI/GDP
Hüttler *et al.* (1997b)	P/MI	GDP/MI	MI/GDP

MI: Material input, *P*: Weight of a product

One concept to measure eco-efficiency is the so-called MIPS-concept, the *M*aterial *I*ntensity per *S*ervice *U*nit (Schmidt-Bleek 1994; 1998; Schmidt-Bleek *et al.* 1998). It measures the total amount of resources that was necessary to produce a certain service unit. In addition to the direct inputs the MIPS includes also materials that were only needed for production and are not becoming part of the product itself, the so-called ecological rucksacks. A service unit refers to the utility gained by a special service such as provision of food or information. For the production of a PC for example it is estimated that about 8 to 14 tons of non-renewable materials are required (Factor 10 Institute 2000, p. 3).

In its report on the *Environment in the European Union at the turn of the century* the *European Environment Agency (EEA)* states that "improved eco-efficiency is not a sufficient condition for sustainable development, as absolute reductions in the use of nature, and associated environmental pressures" would be necessary to achieve this goal (EEA 1999a, p.45). The OECD points out that eco-efficiency is an essential element, but not sufficient for sustainable development (OECD 1998, p. 16).

Spangenberg (2001) developed benchmark criteria for sustainable development. The environmental benchmark condition would be that increases in resource productivity (or eco-efficiency) are at a higher rate than the economic growth rate. Only than could economic growth be environmentally sustainable and absolute resource consumption decrease (Spangenberg 2001, p. 186).

3.4 The rebound effect

Increasing material efficiency does not necessarily lead to an absolute decrease in total material consumption. Gardner and Sampat (1999, p. 51) present several cases where material efficiency of products increased but certain factors undercut these gains in efficiency. For example the weight of aluminium cans was reduced by 30% during the last 20 years. On the other hand they replaced refillable bottles. The weight of mobile phones was decreased by a factor of ten between 1991 and 1996. But the number of subscribers increased 8-fold in the same time and cellular phones did not replace older phones, but have been used in addition to conventional phones. This phenomenon is known as the rebound effect.

A direct and an indirect rebound effect can be distinguished. The direct rebound effect means an increase in the demand for the same type of good due to the cost reduction linked to efficiency increases (Schneider *et al.* 2001, p. 3). This is closely related to efficiency gains through economy of scale in a certain industry. In a broader sense the rebound effect could also lead to technical, organisational and social processes that result in increased consumption in other economic sectors. The rebound effect has been described for money – income gains due to cheaper products lead to more consumption of these products – or time (more efficient organisation of work does not lead to decreasing total working time) but the concept could also be applied to other aspects (for example, physical, spatial, organisational) (ibid.).

Simonis (1994, p. 41) states that three aspects are relevant in de-linking economic activities from environmental pressures: the absolute environmental impact, the impact per capita and the impact per economic output (unit of GDP). Simonis presents an analysis of the resource intensities of four factors (energy, steel, cement, and weight of freight transport) that have been examined for 32 countries for the years 1970 to 1987. Three possible developments have been discovered: structural deterioration (increasing resource intensities), relative structural improvement (relative decline compared to the growth of the economy) and an absolute decline of environmental impacts (ibid. p. 46). The study also points out cases, where relative decreases of resource intensity have been overcompensated by economic growth. If one examines resource intensities for single groups of materials substitution effects (for example, decreasing resource intensity of steel but increasing consumption of steel-substitutes) have to be taken into account (ibid. p. 52). By examining trends of a possible decoupling of economic growth and material use it is important to have in mind that a decoupling itself does not automatically lead to decreasing environmental pressures. Decoupling can take place in parallel with an absolute growth in material consumption and therefore further increasing environmental pressure (Hüttler *et al.* 1997b, p. 113).

If the effects of material use are to be considered on ecological systems it is therefore important to take a look at the total amount of materials extracted. For ecosystems the concept of efficiency is only important as it leads to a decrease of stress factors. The effects on ecosystems depend on the absolute amount of resources extracted. Therefore environmental indicators should be able to describe these total flows.

4. Material flows and the environment in the European Union

In its report on the *Environment in the European Union at the turn of the century* the *European Environment Agency (EEA)* concludes that some progress in solving environmental problems in the EU have been made but that the overall picture is still poor. Many problems – like emission of greenhouse gases, waste levels or soil degradation to just mention some – are expected to worsen in the future (EEA 1999b, p.8).

The environmental status of the accession countries is briefly described in the report. Several problems are expected to be reduced through the implementation of EU environmental laws. On the other hand, increasing consumption and production would increase existing environmental problems. The EEA states, that “in the transition to EU membership, there is a danger that their environment [of the accession countries, the author] will suffer if they follow the same development path of the EU15” and point to the challenge “that they do not repeat the two decades of environmental neglect that occurred in western Europe” (EEA 1999b, p. 32).

4.1 Dematerialisation and eco-efficiency as political goals

The *Factor 10 Institute* – strengthening the need for reducing resource consumption – suggested a global reduction in resource consumption by 50% in order to achieve sustainable development. As 20% of the world population consume 80% of the resources western industrialised countries are requested to dematerialise by a factor of 10 to leave space for development in poorer countries (Factor 10 Institute 2000, p.3).

The *World Commission on Environment and Development* stated in it’s so-called ‘Brundtland-report’ that industrial production should use resources more efficient and that policy should integrate efficiency considerations into economic, trade and other policy domains (World Commission on Environment and Development 1987, pp. 213 and 217).

According to the European Environment Agency (EEA) eco-efficiency has become an "environmental and economic imperative" (EEA 1999a, p. 44). The concept of eco-efficiency has been considered a useful strategy for de-linking pollution and resource use from economic activities by the ministers of the *Organisation for Economic Co-operation and Development (OECD)* (OECD 1998) and de-coupling has been accepted as a necessary target to achieve sustainable development (OECD 2001a, OECD 2001b). The *European Environment Agency (EEA)* has held a workshop on the same topic and views the monitoring and improvement of eco-efficiency as a key objective for all economic sectors (EEA 1999c).

Dematerialisation could be used as a social device (Hinterberger and Schmidt-Bleek 1999) or as ecological guard-rail for an ecological economic policy as described by Hinterberger *et al.* (1996).

Dematerialisation would also lead to a reduction of output flows. As by the law of the conservation of mass everything what physically enters an economy has to leave it at any point of time a reduction of material inputs must lead to a reduction of (current or future) output. Hekkert *et al.* showed the potential for a reduction of CO_2 emissions by dematerialisation of packaging (Hekkert 2002; Hekkert *et al.* 2000a; Hekkert *et al.* 2000b).

5. Methodology

5.1 The concept of industrial/societal metabolism

Within the concept of industrial or societal metabolism sustainability problems are viewed as problems of the material and energetic relationships between society and nature (Fischer-Kowalski and Haberl 1997, p. 3). An analogy is drawn between biological organisms and industrial systems. Both need inputs of energy and materials for the maintenance of their functions. These inputs are transformed and leave the system as products or wastes. Therefore industrial metabolism can be defined as "the whole integrated collection of physical processes that convert raw materials and energy, plus labour, into finished products and wastes" (Ayres 1994, p. 3).

A history of the concept of metabolism in social sciences (social theory, anthropology, geography) for the years 1860 to 1970 has been presented by Fischer-Kowalski (1998). Ayres and Kneese (1969) have introduced this concept into economic theory and thus laid the foundations for economy-wide material flow analyses. The history of material flow analysis for the years 1970 to 1998 has been documented by Fischer-Kowalski and Hüttler (1999).

According to the classification principles of Fischer-Kowalski and Hüttler (1999, pp. 109) material flow analyses (MFA) can be classified by four criteria:

The first criterion is a comprehensive perspective, which can focus on a socio-economic system and/or the ecosystem.

The second one is the reference system. This can be the global anthroposphere or biosphere, a national or regional system or a functional unit, like households or sectors.

The third criterion refers to the examined material flows. In a socio-economic perspective this can be the "(bulk) total material metabolism", energy flows or specific materials (for example, chemicals, metals). One can consider inputs, outputs or both. In an ecosystem perspective flows are compared to resource availability, changes of natural stocks, absorption capacity or reference flows within the natural system.

The fourth criterion deals with the time-aspect (point in time, time series, long-range historical perspective). The study presented here analyses the metabolism of the socio-economic system of a national economy in a short time series.

According to the OECD (2000) two broad categories of material flow analyses are distinguished. One deals with environmental problems related to certain impacts of substances (for example, lead or mercury), materials (for example, wood or energy carriers) or products, which is the focus of Life Cycle Analyses). The second group of MFA deals with problems related to the overall throughput of firms, sectors or regions. In this paper two basic intentions for MFA are pointed out: detoxification and dematerialisation. In this classification the impact and substance-based approach follows more the concern of detoxification (for a collection of case studies see Ayres and Simonis 1994; for the example of a case study on heavy metal pollution in central Europe see Anderberg *et al.* (2000). Economy-wide MFA, like this study, in following the target of dematerialisation, examines the total throughput of economies.

5.2 The methodology of economy-wide material flow accounting

An economy-wide material flow analysis measures the total amount of resources that was necessary to enable the activities of an economy. The data of the material basis of an economy (or its scale or metabolism) is collected disaggregated by material categories for single years and aggregated to derive overall indicators of resource use.

Economy-wide material flow analyses have recently been published or are in progress for a number of countries: Germany, Japan, the Netherlands and the United States (Adriaanse *et al.* 1997, Matthews *et al.* 2000), Australia (Durney --), Austria (Gerhold and Petrovic 2000, Schandl *et al.* 2000, Eurostat 2000, Schandl 1998, Wolf *et al.* 1998, BMUJF 1996, Matthews *et al.* 2000), China (Chen and Qiao 2000, in Chinese with English abstract; Chen and Qiao 2001), Finland (Muukkonen 2000, Ministry of the Environment 1999, Mäenpää and Juutinen 2000, Juutinen and Mäenpää 1999), Italy (De Marco *et al.* 2001, Femia 2000), Japan (Moriguchi 2001), Poland (Mündl *et al.* 1999, Schütz and Welfens 2000), Sweden (Isacsson *et al.* 2000), United Kingdom (Schandl and Schulz 2002, Schandl and Schulz 2000, Sheerin 2002, Bringezu and Schütz 2001d), France (Chabannes 1998), Brazil (Machado 2001, Amann *et al.* 2002), Venezuela (Castellano 2001, Amann *et al.* 2002), Bolivia (Amann *et al.* 2002), and the European Union (Eurostat 2002, Bringezu and Schütz 2001a, b, c).

National material accounts exist further for Denmark and are in work for Egypt (mentioned in OECD 2000, p. 7). A group of scientists at the Environment Center of the Charles University (Prague) is at present working on the compilation of material flow indicators and balances of the Czech Republic.

Several countries have integrated material flow statistics into their official statistics or are planning to do so (Austria, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands and Sweden, according to Fischer-Kowalski and Hüttler 1999). The United Nations integrated physical flow accounts into its *System of Environmental and Economic Accounting* (SEEA) (UN 2000c).

The methodologies that have been applied for these studies vary in their details of calculation, the exclusion or inclusion of certain flows, the used terminology, or the system boundaries between nature and economy. Eurostat (2001) published a methodological guide that has been elaborated by researchers of this field and provides a common terminology and methodology for economy-wide material flow analysis.

5.2.1 Categories of material flows and system boundaries

According to Eurostat (2001, p. 20) material flows can be characterised by three dimensions (see also Table 2):

The first dimension is territorial and indicates the origin or destination of the flows, domestic or foreign. Domestic flows are extracted from or released to the national environment.

The second dimension is a product-chain or life cycle dimension accounting for direct and indirect flows. Direct flows enter the national economy physically as input. Indirect flows occur up-stream in the production process. As the economy is treated as a black box in an economy-wide material flow analysis no indirect flows of the national production process have been evaluated.

The third dimension – the product dimension – tells us whether materials enter any economic system or not: used or unused. Unused flows are materials that have been extracted from the environment, but never entered the economy for further processing.

Table 2: Terminology of material input categories

Life cycle dimension	Product dimension	Territorial dimension	Input category
Direct	Used	Domestic	Domestic extraction (used)
Not applied	Unused	Domestic	Unused domestic extraction
Direct	Used	Foreign	Imports
Indirect	Used	Foreign	Indirect flows associated to imports
Indirect	Unused	Foreign	

Source: modified from EUROSTAT 2001, p. 20.

Material inputs can be described by four categories as shown in the right column of Table 2. Domestic extraction (used) contains materials that are extracted from the national environment and enter the economy for further processing. This includes materials that enter the economy and either become part of a product or appear as waste during the production process. For example, the total weight of a metal ore is by convention of Eurostat classified as material input of domestic extraction (Eurostat 2001, p. 46). But this includes not only the metal – later be found in products – but also ancillary mass, which becomes waste during the production process. Unused domestic extraction consists of flows that were extracted from the national environment, but do not become part of a product or a production process. For example, soil and rocks covering metal ores to be removed to get access to the ores are overburden waste and do not enter economic production. The borders of the economy or of production processes are not self-evident, they have to be defined. For example, in previous studies the ancillary mass of metal ores has been accounted as unused flows. The methodological guide from Eurostat provides detailed definitions, so that forthcoming studies can be undertaken and compared on a common basis.

The term *Imports* refers to all commodities as reported by trade statistics. Indirect flows associated to imports consist of two parts. Used indirect flows enter the exporting economy and are used to produce the imported commodity (for example, the ancillary mass of a metal ore). Unused foreign flows do not enter the production process of the exporting economy (for example, overburden of foreign metal extraction). These two components of indirect flows are not reported separately in this study. Indirect flows associated to exports do not enter the importing country but remain as waste in the export country. Therefore a shift of production to foreign countries could also shift the environmental pressure generated by material extraction to these countries.

Output flows can be categorised by similar criteria. The criteria used/unused is here called processed/non-processed. And the distinction domestic foreign refers to the destination of material flows. The overview of output categories is given in Table 3.

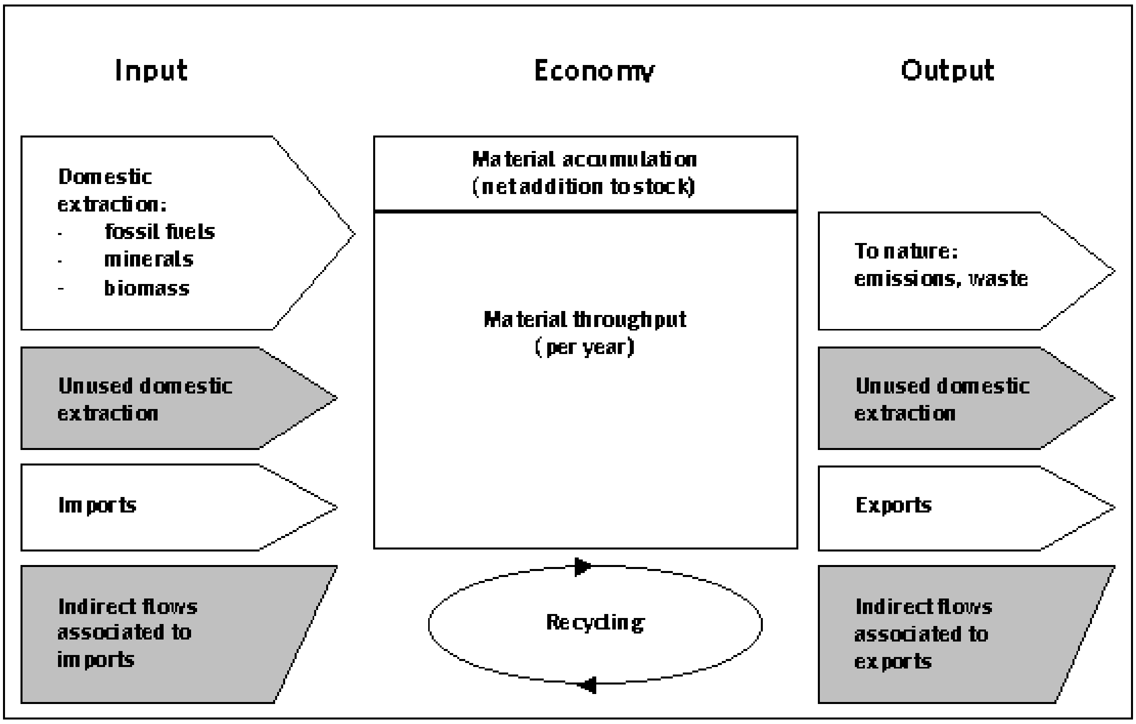
Table 3: Terminology of material output categories

Life cycle dimension	Product dimension	Territorial dimension	Output category
Direct	Processed	Domestic	Domestic processed output to nature
Not applied	Non-processed	Domestic	Disposal of unused domestic extraction
Direct	Processed	Foreign	Exports
Indirect	Processed	Foreign	Indirect flows associated to exports
Indirect	Non-processed	Foreign	

Source: modified from EUROSTAT 2001, p. 20.

What has until recently been described as ecological rucksacks (Schmidt-Bleek 1994, Schmidt-Bleek 1998, Schmidt-Bleek *et al.* 1998, Mündl *et al.* 1999) or hidden flows (Adriaanse *et al.* 1997, Bringezu and Schütz 2001a) is defined in further detail by Eurostat (2001, p. 20). Ecological rucksack means "the entire life-cycle-wide material input (MI) deducted by the own weight of the product," which was necessary to produce the product (Schmidt-Bleek *et al.* 1998, p. 27). This includes both used and unused flows. Eurostat (2001) differentiates between indirect flows and hidden flows that form the ecological rucksack. Indirect flows are defined as "up-stream material input flows that are associated to imports, but are not physically imported." These flows can either be used (for example, materials used by the exporting country for the production of traded goods and staying in the exporting country as production waste) or unused (materials as by-product of resource extraction remaining within the exporting country). Hidden flows refer to unused materials associated with the extraction of raw materials, both nationally and abroad. Therefore unused domestic extraction could be called 'domestic hidden flows'. Indirect flows of unused extraction associated to imports could be called 'foreign hidden flows (associated to imports)' (Eurostat 2001, p. 22). As only used domestic extraction and imports and parts of the indirect flows associated to imports are reported in economic production and trade statistics unused domestic extraction and indirect flows associated to imports had to be calculated as described in the technical annex of this work. Figure 1 provides a graphical description of these.

Figure 1: Economy-wide material flow balance



Source: Modified after EUROSTAT (2001)

The system boundary between nature and economy is defined "by the extraction of primary (…) materials from the national environment and the discharge of materials to the national environment" and the system boundaries between economies are defined "by the political (administrative) borders that determine material flows to and from the rest of the world (imports and exports)" (Eurostat 2001, p. 17). But this definition does not clearly state what is part of the environment or of the socio-economic system (for a discussion of this aspect see Fischer-Kowalski and Hüttler 1999, pp. 114 and Fischer-Kowalski 1997). Livestock and plants, for example, could be treated as part of the environment and their harvest and products (for example, milk) would be inputs to the economy. Or they could be seen as a compartment of the society. Then the food of the animals or the nutrition taken up by plants would be the material input. Eurostat suggests considering livestock as part of the economy (Eurostat 2001, p. 17). Therefore meat and other products from animals are not part of domestic extraction. Cultivated plants and forest on the other hand are considered to be part of the nature and production of agricultural and wood products is included in domestic extraction. These distinctions also influence the definitions of stocks and flows. After a comparison of the results of material flow analyses of Japan, Germany and Austria Hüttler *et al.* (1997a, p. 75) state that the differences in the results between industrialised countries caused by different sets of system boundaries are bigger than differences caused by production technologies or consumption behaviour. They express the need for international harmonisation of methodologies in material flow accounting, which has recently been provided by Eurostat (2001).

Water flows are excluded in this scheme, as they represent enormous mass flows of one order of magnitude more than all other materials (ibid. 2001, p. 16). Further, flows of air are excluded from this study, as they are not treated as material inputs for the derivation of input indicators (ibid. p. 28). Also soil erosion is not part of the derived indicators (ibid. p. 49) and therefore not accounted for in this study, although it has been included in other publications (Adriaanse *et al.* 1997, Mündl *et al.* 1999, Bringezu and Schütz 2001a). In their overview Fischer-Kowalski and Hüttler (1999, p. 117) state, that water and air tend to be excluded from material flow analyses for not "drowning" the economically valued raw materials, as air and water would account for about 85 to 90% of total material flows.

The methodological guide provides a detailed classification of material categories (Eurostat 2001, pp. 28 and pp. 75) that was used for the arrangement of the data in this study. The inputs are first divided into domestic extraction and imports. Domestic extraction is separated into broad material categories (fossil fuels, metal ores, minerals, and biomass). Each material category is than further disaggregated. Imports are separated into raw materials, semi-manufactured products and finished products and each of these groups is again disaggregated by material categories. Semi-manufactured and (some) finished products have been allocated to the material category that establishes its largest share. A precise allocation of selected import data to material categories is possible as for each commodity the code of the commodity classification used by international trade classification systems is reported in the Eurostat guide. This allows the comparability of different studies following this guide.

5.2.2 Indicators of material flows

Several input and consumption indicators can be derived from material flow accounts (Eurostat 2001, pp 35):

Input Indicators:

Direct Material Input (DMI): Materials used in the economy for further processing. This equals domestic extraction plus imports.

Total Material Input (TMI): Including additionally the unused domestic extraction. These are materials moved by extraction but not entering the economy. (DMI + unused domestic extraction).

Total Material Requirement (TMR): Includes also indirect flows associated with imports and therefore taking place in other countries. (DMI + unused domestic extraction + indirect flows associated to imports).

Domestic total material requirement (domestic TMR): Domestic used and unused extraction.

Consumption indicators:

Domestic Material Consumption (DMC): DMI minus exports.

Total Material Consumption (TMC): TMR minus exports and their indirect flows.

Net Addition to Stocks (NAS): The 'physical growth of the economy' in form of new buildings or durable goods.

Physical Trade Balance (PTB): Import minus exports (optionally including indirect flows associated to imports and exports). Measures the physical trade surplus or deficit of an economy.

Output indicators:

Domestic Processed Output (DPO): Total weight of materials which have been used in the domestic economy before flowing to the environment, including emissions to air, wastes deposited in landfills, material loads in waste water and materials dispersed into the environment as a result of product use (dissipative flows).

Total domestic Output (TDO): Sum of DPO and unused extraction; the total quantity of material outputs to the environment.

Direct Material Output (DMO): The sum of DPO and exports.

Total Material Output (TMO): TDO plus exports.

The input indicators (except for domestic TMR) are not additive across nations. For the total TMR of a group of countries the inter-country trade has to be netted out. Adding up TMRs would lead to double-counting as the materials of the imports of country B stemming from country A would already be included in the TMR of country A as either domestic extraction or imports from a another country. DMO and TMO are also not additive across countries. The concept of TMR leads to the result, that TMR of countries with high-resource intensive production (for example, lignite mining) is notably high, irrespective of whether the produced materials are exported or consumed by the countries population itself (Bringezu and Schütz 2001a, p. 8). The choice for one of these indicators may depend on the research question or political aim. Input indicators provide a better picture of modes of production, whereas consumption indicators are more related to the resident's needs and their standard of living. Total requirement indicators (TMR, TMC) can provide information on global ecological impacts and effects of international trade. Direct flow indicators (DMI, DMC) are more related to national policies and economic aspects, as they report only materials entering the economy (Eurostat 2001, p. 43). It should be mentioned that DMC does not measure 'real' consumption of a country (for example in the sense that this 'consumption' contributed to a higher material standard of living) as it includes materials that have been used for producing exports which are consumed by other countries. These materials used for the production of exports are part of the material input and stay within the country as wastes of export production thereby increasing DMC. Therefore, TMC would provide a better indicator of consumption as the production wastes of export production are excluded from the indicator by subtracting indirect flows associated to exports.

6. Case study: Material flow accounts for Hungary

6.1 Macroeconomic developments

GDP of the Hungarian economy dropped by 18.9% from 1988 to 1992, 7.9% due to the direct and indirect effects of the loss of export markets and GDP growth was negative until 1994. Main reasons have been the collapse of demand in eastern European countries and countries of the former Soviet Union and a disruption of old distribution networks and supplier-user connections. Furthermore, traditional domestic suppliers have been crowded out by foreign ones. Production of goods and services not demanded anymore dropped instantly and the development of newly demanded supply needed time. A substantial drop of output could be observed for the industry. In 1992 real gross industrial production was 32% lower than in 1989 and recovered to its pre-transition level not before 1998. Gross agricultural output fell by 35% until 1993 and its recovery to the 1989 level is not expected in the near future. Housing construction declined by 60% until 1994 and in 1998 still stood at that level. After the years of output decline several sectors (particularly engineering) began to grow rapidly. Among the macroeconomic indicators the smallest decline could be observed for aggregate trade figures, which experienced a major geographical and sectoral restructuring. Unemployment reached 13.3% in 1993 and stayed around 10% in 1997-1999. The share of long-term unemployment reached 45-50% in the second half of the 1990s (Gács 2000, pp. 5). Forecasts of long run potential growth vary substantially with growth rates between 3.00 and 5.28%. These growth rates mean that Hungary would need between 65 and 20 years to reach the average per capita income level of the three poorest countries of the European Union (Greece, Ireland and Portugal), assuming that they will grow by 2% per year (ibid., p. 13). An increase in investment into physical capital can be expected as "much of the amount of physical capital established during the time of central planning was over-investment or misallocated investments that could not be converted to other productive activities in the new system" (ibid., p. 15, quoting Borensztein and Montiel 1991).

The Hungarian economy relies strongly on foreign trade. Without the substantially expanding level of exports GDP growth would not have been realised between 1990 and 1999. The Hungarian export performance was strongly influenced by demand levels of the European Union, especially of Germany. In the future exports are expected to remain strongly linked to the demand level of the European Union and beneficial growth effects could arise from economies of scale of a single large market after accession to the European Union (ibid., pp 18 and 32).

6.2 Data compilation

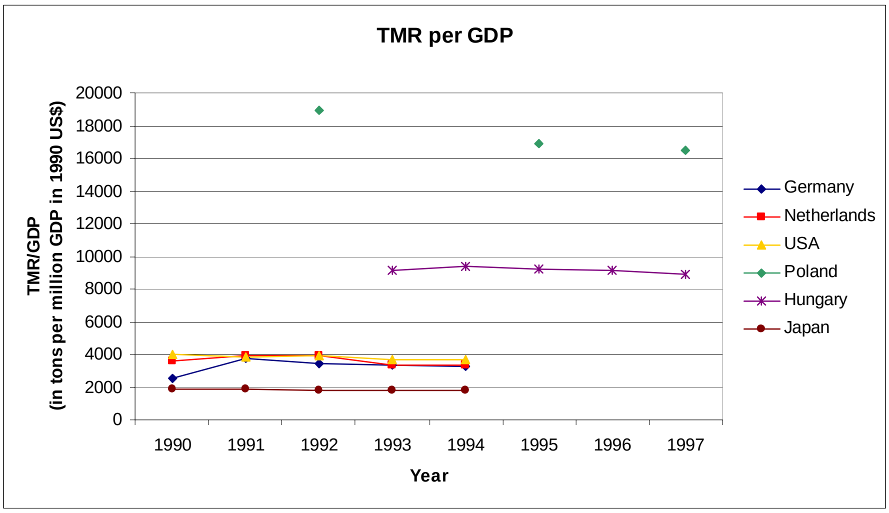
For the calculation of material flow accounts data on production and international trade in physical terms is essential. Data for domestic extraction and imports has been taken from various international statistical sources from the United Nations (UN 1997a, b; 1999a, b; 2000a, b; UCTAD and WTO ---; FAO 2001, and http://apps.fao.org), OECD (OECD/IEA 1998, 2000), and US Geological Survey (USGS ---) which report production and trade in monetary and physical terms. In this study no correction of these official data has been undertaken. This may be important in cases where these official statistics systematically do not account for certain types of production (for example, the production of sand and gravel by small enterprises, as mentioned by Hüttler *et al.* (1997a, p. 75 and 121). Furthermore, these statistical sources do only partially report data on unused and indirect flows. These material flows had to be calculated by the use of product-related coefficients, which were taken from various publications and are mainly based on calculations of the Wuppertal Institute. A detailed description of the data sources used and the calculation of material flows is given in Appendix 1.

6.3 Results

6.3.1 Material input and consumption in international comparison

A comparison of the TMR of Hungary with the TMR of other countries is shown in Figure 2 and Figure 3. TMR per GDP for Hungary is about 9,000 tons per million GDP in constant 1990 US$ and shows a slight increase for the first year and a decrease for the last three years. TMR per GDP can be taken as a measure for the material intensity of an economy. Therefore, the material intensity of the Hungarian economy lies between the material intensities of western industrialised countries which are significantly lower, and the one of Poland which is almost twice as large as the one of Hungary. So it can be stated, that the eco-efficiency of the Hungarian economy staid more or less constant although showing a moderate increasing trend since 1994.

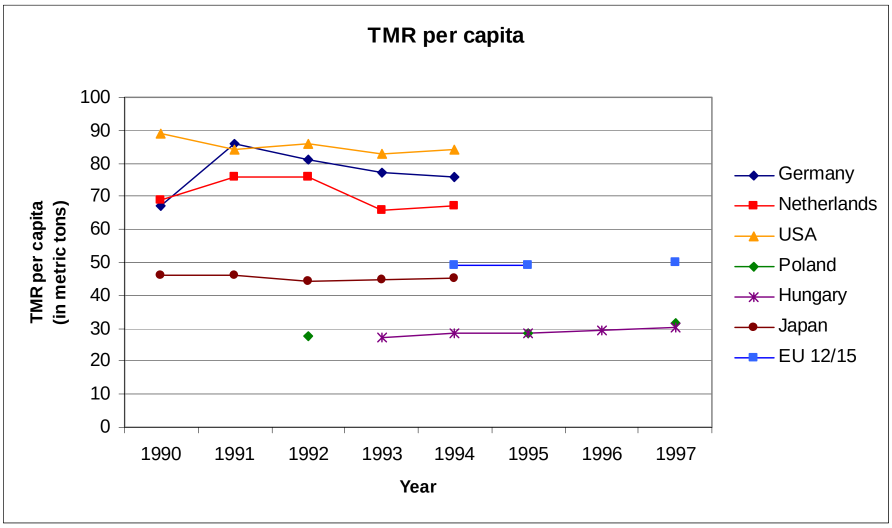
Figure 2: Material input intensities



Source: Adriaanse *et al.* (1997), Bringezu and Schütz (2001a), Mündl *et al.* (1999) and United Nations Statistical Yearbook (various years), own calculations.

A look at the TMR per capita (Figure 3) of the same countries provides a quite different picture. TMR per capita for Hungary between 1993 and 1997 increased from 27 to 30 tons per capita and year and therefore nearly equals the TMR per capita in Poland. Material inputs per capita for these eastern European countries are significantly lower than in western industrialised countries.

Figure 3: Material inputs per capita

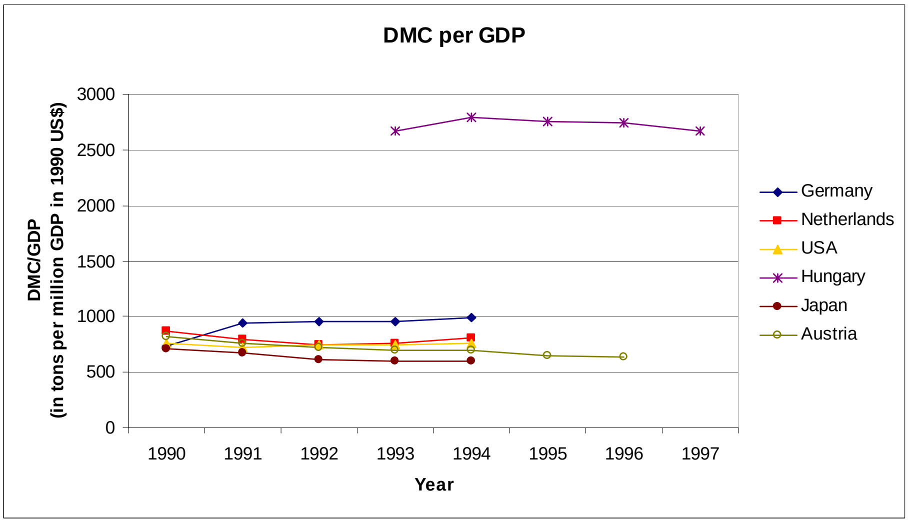


Source: Adriaanse *et al.* (1997), Bringezu and Schütz (2001a), Mündl *et al.* (1999) and United Nations Statistical Yearbook (various years), own calculations.

It has to be mentioned that in the studies used for this comparisons slightly different methodologies have been used. For example, the studies on western industrialised countries and Poland include erosion. For Poland erosion accounts for about 9% of TMR or 2.6 tons per capita and year (Mündl *et al.* 1999, annex 4, tables 1 and 2). Due to the suggestions of Eurostat (2001) this category has not been included in this study.

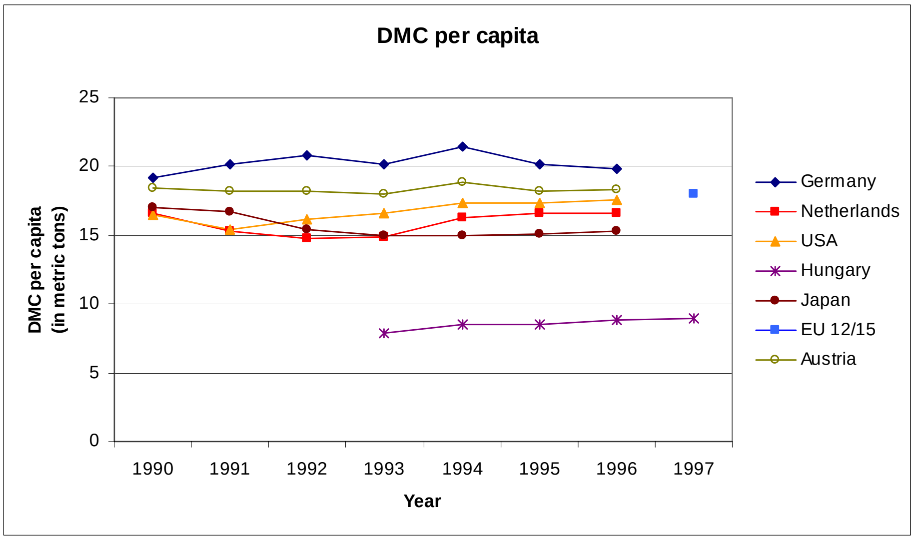
If Domestic Material Consumption indicators (DMC) are compared between these countries – as shown in Figure 4 and Figure 5 - a similar picture as for TMR is seen. DMC per unit of GDP is higher in Hungary than in western European countries, whereas per capita DMC is lower. DMC/GDP for Hungary accounted for about 2,700 tons per million dollar at 1990 prices. DMC/capita is about 9 tons per year. TMC/GDP and TMC/capita accounted for about 8,000 tons per million dollar and 26 tons per capita. As no TMC for other countries is available no comparison for TMC could be made.

Figure 4: Material consumption intensities



Source: Matthews (2000), United Nations Statistical Yearbook (various years), own calculations. Values for Austria in ton per million 1995 US$.

Figure 5: Material consumption per capita

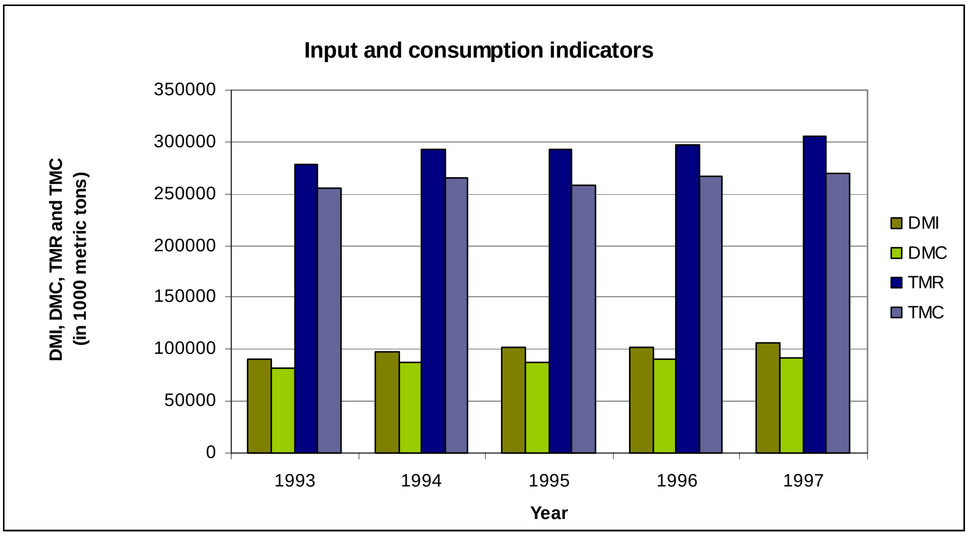


Source: Matthews (2000), Bringezu and Schütz (2001b), United Nations Statistical Yearbook (various years), own calculations.

6.3.2 Inputs versus consumption

Figure 6 shows the relation between input and consumption indicators. For Hungary material consumption is of a magnitude of about 90% of material inputs. This share can vary substantially between countries. In export economies (like for example the Netherlands or Venezuela) exports can amount to close to 50% of material inputs (Fischer-Kowalski and Amann 2001, p. 34).

Figure 6: Material inputs versus material consumption in Hungary

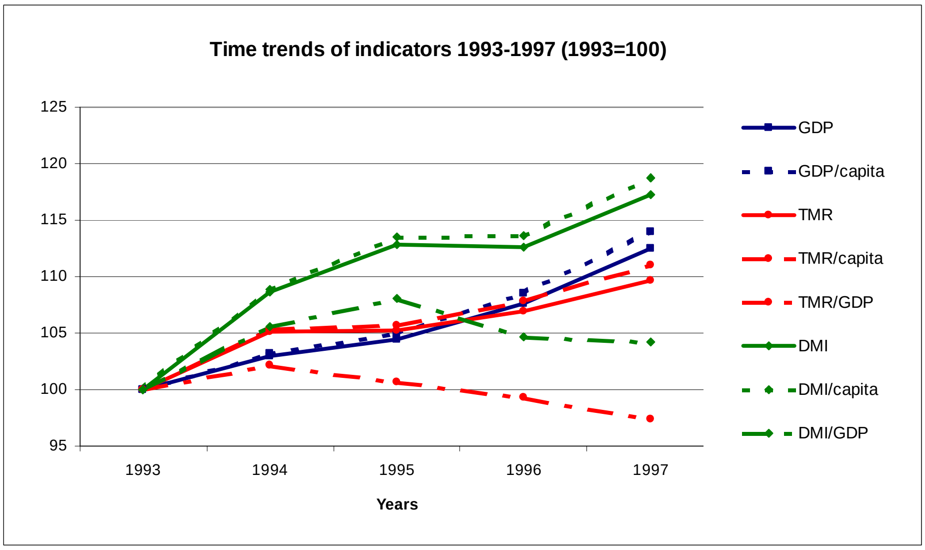


Source: Own calculations.

6.3.3 Time trends

An analysis of the time trend of our indicators shows that TMR and TMR/capita seem to grow more or less parallel with GDP and GDP per capita. During the first years TMR was growing faster than GDP, but than growth of TMR decreased. Over the five years examined TMR has increased by 10% and GDP has grown by 13%. DMI and DMI/capita have grown even faster. They have increased by more than 17% (DMI) and 19% (DMI/capita) between 1993 and 1997. The changes in DMI/GDP and TMR/GDP do not allow a clear statement on decoupling. After an increase during the first two years both started to fall later. DMI per GDP increased until 1995 and is in 1997 still above the level of 1993. TMR per GDP increased during the first year and has until 1996 fallen even beneath the level of 1993. So a trend of relative decoupling of inputs from GDP are seen for the last years. An absolute decoupling cannot be seen, as the absolute amounts of material inputs and the inputs per capita increased. The same trend – relative decoupling by an absolute increase of material requirements – has been examined for other countries (Adriaanse *et al.* 1997, Schandl 1998, Mündl *et al.* 1999, Bringezu and Schütz 2001a). It has to be mentioned here that the time series of this study is very short covering only five years. A longer time series would have a potential for a better analysis of decoupling trends.

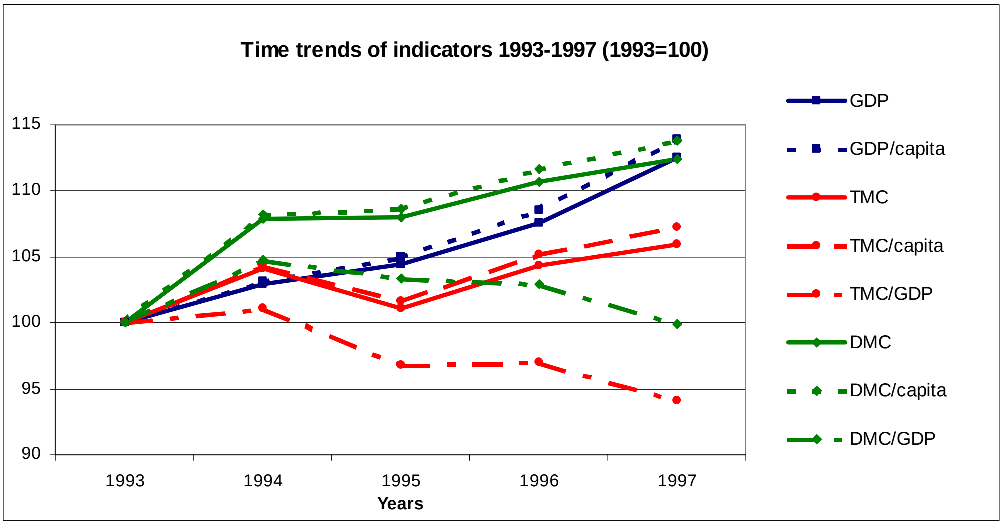
Figure 7: Time trends of indicators I



Source: United Nations Statistical Yearbook (various years), own calculations.

The time trends for consumption indicators show a similar picture, although a clearer trend for decoupling occurs for TMC/GDP. But again decoupling only takes place in relative terms. Absolute and per capita numbers of consumption indicators show an increasing trend.

Figure 8: Time trends of indicators II

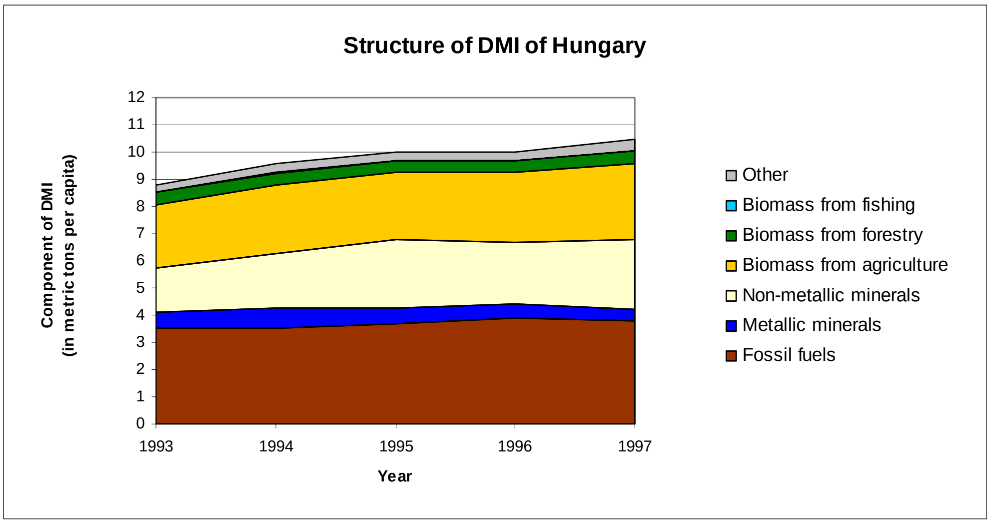


Source: United Nations Statistical Yearbook (various years), own calculations.

6.3.4 *Disaggregation by material components*

A disaggregation of the material inputs of the Hungarian economy by material categories is shown in Figure 9 and Figure 10. Figure 9 shows the share of various material components on the Direct Material Input (DMI) of Hungary. It can be seen that fossil fuels are the largest component of DMI accounting for more than 36% of DMI in 1997. Biomass from agriculture (27% in 1997) is the second largest component, followed by non-metallic minerals with 25% in 1997. A DMI per capita of non-metallic minerals of 2.6 tons per year is quite low compared to other industrialised countries where this number can be around 10 tons per capita and year (Haberl, Amann, Erb; personal communication). Therefore, one has to keep in mind that official statistics are sometimes incomplete. An evaluation and correction of this possible error would be a task affording a considerable amount of time and therefore lies beyond the scope of this thesis.

Figure 9: Material components of Direct Material Input (DMI)

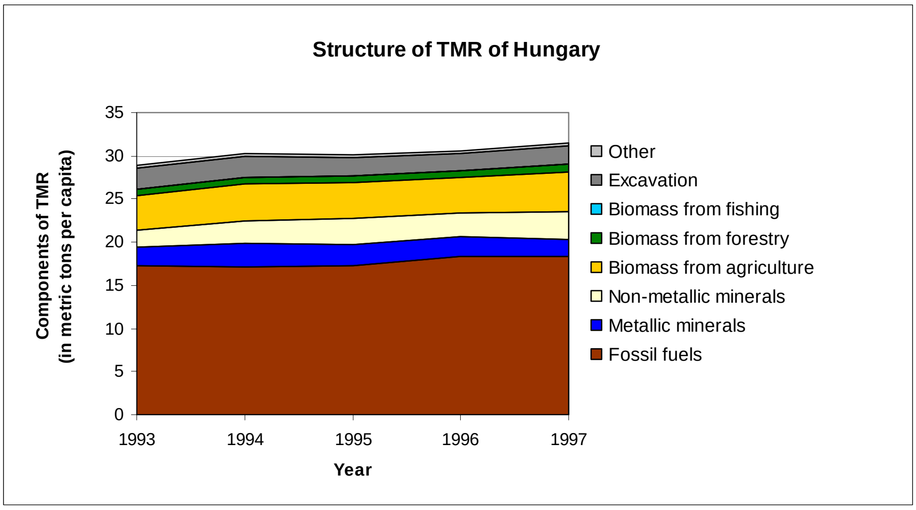


Source: Own calculations.

The fastest increasing material component of DMI is the one of non-metallic minerals which increased (with huge fluctuations) by 59% within this five years. The second largest increase can be seen for direct inputs from forestry which increased by 20%. Only direct inputs for metallic minerals decreased (by 23%). The other categories showed a slight increase of less than 10%.

The share of material throughput on TMR induced by fossil fuels is even larger. Material flows induced by use of fossil fuels account for 61% of the Hungarian TMR in 1997. This even higher share is a result of the high coefficients for hidden flows of lignite. Lignite extraction (used) accounts for about 5% of TMR. Due to a coefficient for unused extraction of 8.13 tons per ton of lignite (taken from Bringezu and Schütz 2001c, see Appendix 1 for further details of calculation) the amount of unused domestic extraction of lignite is responsible for about 40% of TMR and is therefore the largest flow category. Biomass from agriculture (15%) and non-metallic minerals (11%) are again the second and third largest groups. In the figure of material categories of TMR the numbers include all material flows that were induced by the use of a certain material category. This means that the area 'fossil fuels' shows not only the flows of fossil fuels, but also the flows of all materials associated to the flows of fossil fuels (unused domestic extraction and indirect flows associated to imports). Therefore, each area consists of several material categories and only shows the share of overall flows due to the use of a material category on TMR. The ratios of unused extraction for this study have been taken from published data which is mainly based on Germany but vary significantly between countries depending on production technology. The influence of the unused extraction ratio of lignite on the overall indicator shows how a more detailed estimation of unused extraction in Hungary (or in the investigated country in general) could improve the quality of the results compared with the methodology of applying the German factors to other countries as used in this study.

Figure 10: "Material components" of Total Material Requirement (TMR)



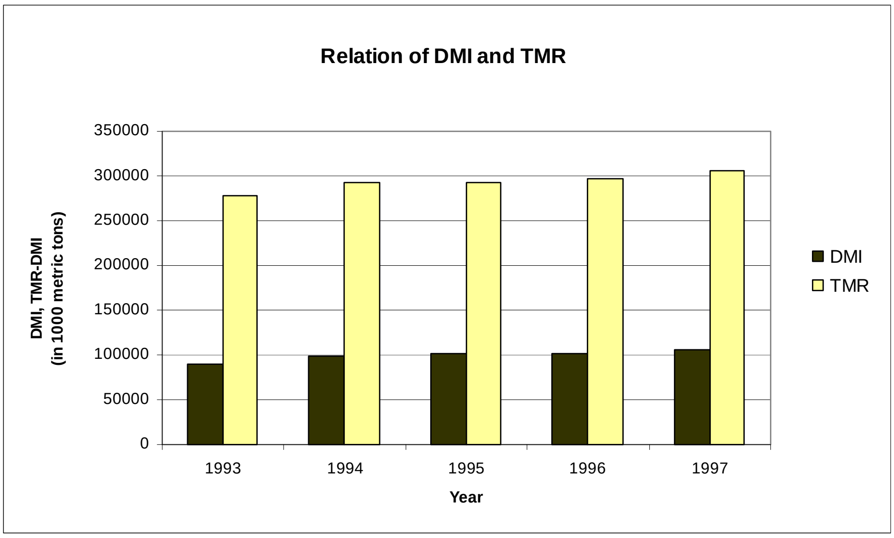
Source: Own calculations.

Material flows of fossil fuels not only dominate the TMR of Hungary. Fossil fuels are – to different shares – also the largest component of TMRs of Germany, the Netherlands, the United States and Poland (Adriaanse *et al.* 1997, Mündl *et al.* 1999).

6.3.5 Direct and hidden flows

Figure 11 shows DMI and TMR in absolute numbers. The difference between these two indicators results from the so-called hidden flows (consisting of unused domestic extraction and indirect flows associated to imports). Hidden flows in 1997 contributed to 65% of TMR. Therefore more than half of the material flows induced by economic activities in Hungary never entered the Hungarian economy. It has to be noted, that indirect flows have not been accounted for imported finished products (except for agriculture and forestry) and therefore this figure still represents an underestimation of hidden flows. Hidden flows also dominate the TMR of other countries. Hidden flows for the four western industrialised countries examined by the World Resource Institute account for 55 to 75% of TMR (Adriaanse *et al.* 1997, p. 12).

Figure 11: Direct and hidden flows

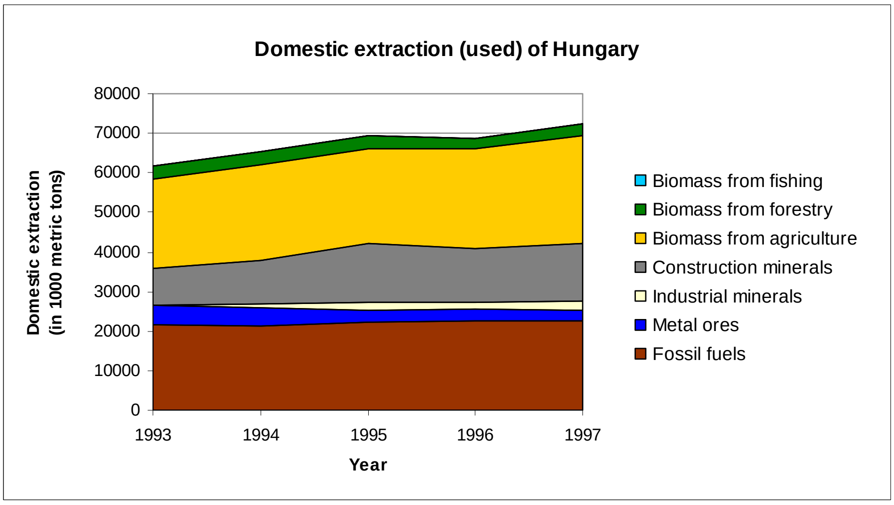


Source: Own calculations.

6.3.6 Domestic extraction

Except for 1993 agriculture has been the largest contributor to used domestic extraction in Hungary with a share of 34% in 1997. In this year, all biomass contributed for 39% of used domestic extraction, fossil fuels for 28% and minerals and ores for 34%. In the last group construction minerals contribute most to domestic extraction with 18% of used domestic extraction.

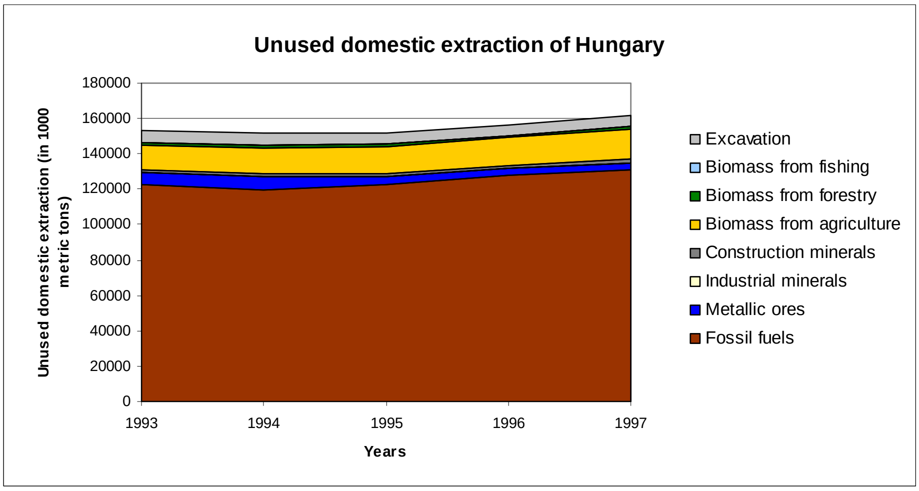
Figure 12: Structure of domestic extraction



Source: Own calculation.

Unused domestic extraction on the other hand shows again the picture of the dominance of fossil fuels, activating 80% of unused domestic extraction. This leads to a share of unused domestic extraction on TMR of 54% in 1997, 42% due to unused domestic extraction of lignite mining. Again it has to be noted that what is called “fossil fuels” in this chart does not represent fossil fuels itself, but the unused domestic extraction of the extraction of fossil fuels. This also holds for the other “material categories”.

Figure 13: "Material categories" of unused domestic extraction.

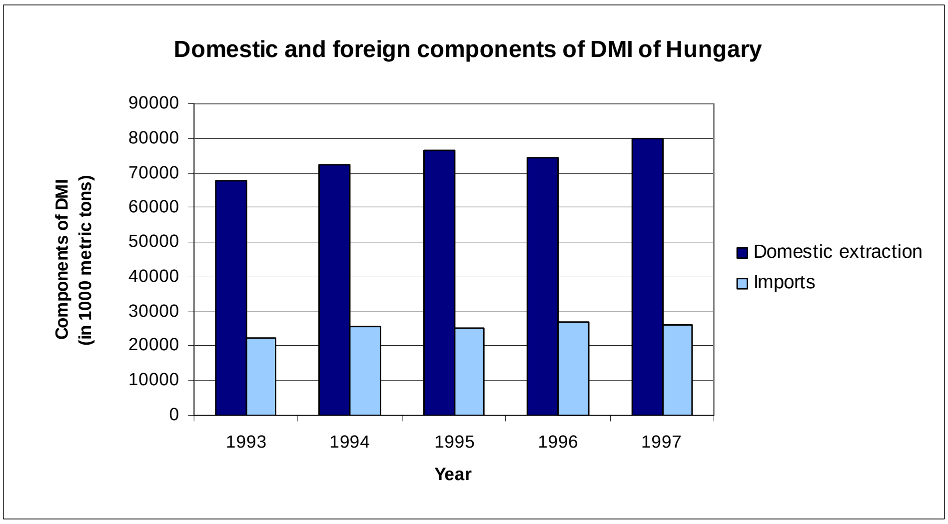


Source: Own calculation based on coefficients by Bringezu and Schütz (various years).

6.3.7 Imports and exports

Imports account for about 25% of DMI, which is shown in Figure 14 . Imports plus indirect flows associated to them contribute to about 20 to 23% of TMR. Therefore Hungary is quite self-sufficient in providing its resource flows. The proportions of domestic extraction and imports on TMR can vary widely between different countries. The foreign components of TMR of the United States and Poland are even smaller, whereas for Japan and the Netherlands these components are larger than the domestic components of TMR (Adriaanse *et al.* 1997, Mündl *et al.* 1999).

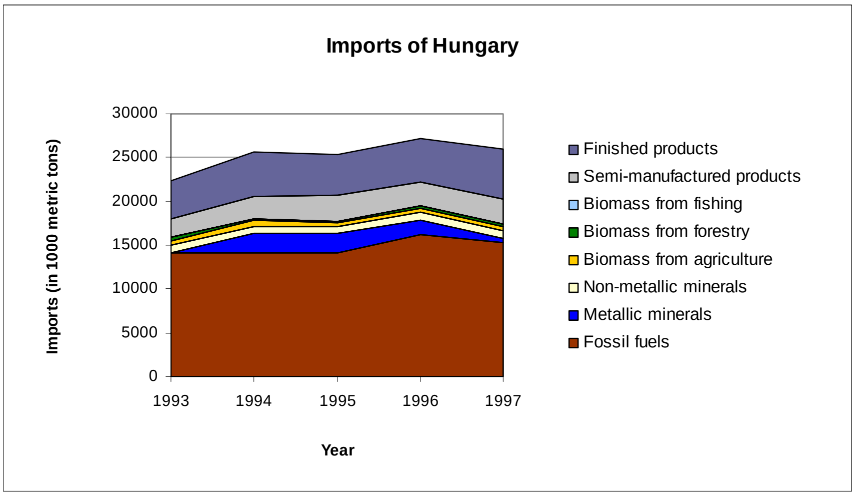
Figure 14: Foreign and domestic components of Direct Material Input (DMI)



Source: Own calculation.

Looking at the structure of material imports to Hungary as shown in Figure 15 (showing raw materials disaggregated by material categories and aggregates of semi-manufactured and finished products) it can be seen that they are clearly dominated by fossil fuels. With about 14 to 16 million tons fossil fuels account for about 60% of total imports (including raw materials, semi-manufactured and finished products). Natural gas and crude petroleum are the two largest components within imported fossil fuels. Raw materials accounted for about 67% of all imports in 1997.

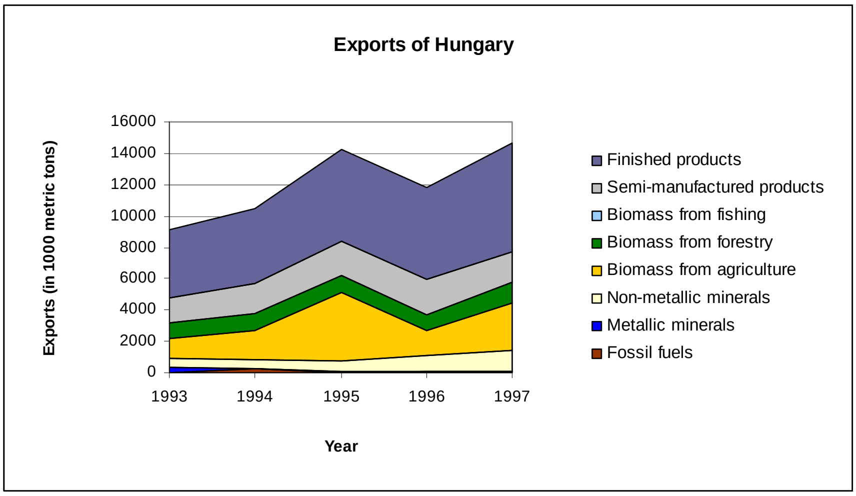
Figure 15: Import structure



Source: Own calculation.

Exports show a much higher share of semi-manufactured and finished products. Beside finished products the following material categories are the largest among exports (listed with falling absolute amounts of 1997): Biomass from agriculture, semi-manufactured from metallic minerals, biomass from forestry, non-metallic minerals and agricultural plant products. The fastest growing categories of these have been non-metallic minerals, biomass from agriculture (with huge fluctuations) and agricultural plant products.

Figure 16: Export structure

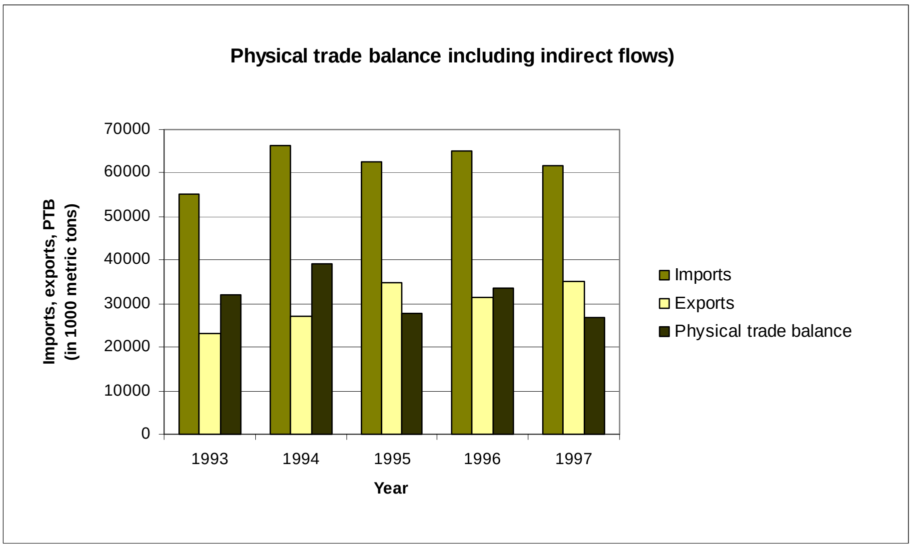


Source: own calculations.

6.3.8 Physical trade balance

Imports exceed exports in all five years. This physical trade surplus of direct flows accounted for about 44 to 59% of imports, showing no clear trend over the five years. The physical trade balance of total flows (including indirect flows associated to imports and exports) is of the same magnitude. In the European Union PTB accounts for about 70% of imports (Bringezu and Schütz 2001b, p.43; Giljum and Hubacek 2001, p. 34). Examples of southern countries in which physical exports exceed imports have already been discussed in a previous chapter. Figure 17 shows the physical trade balance of total flows.

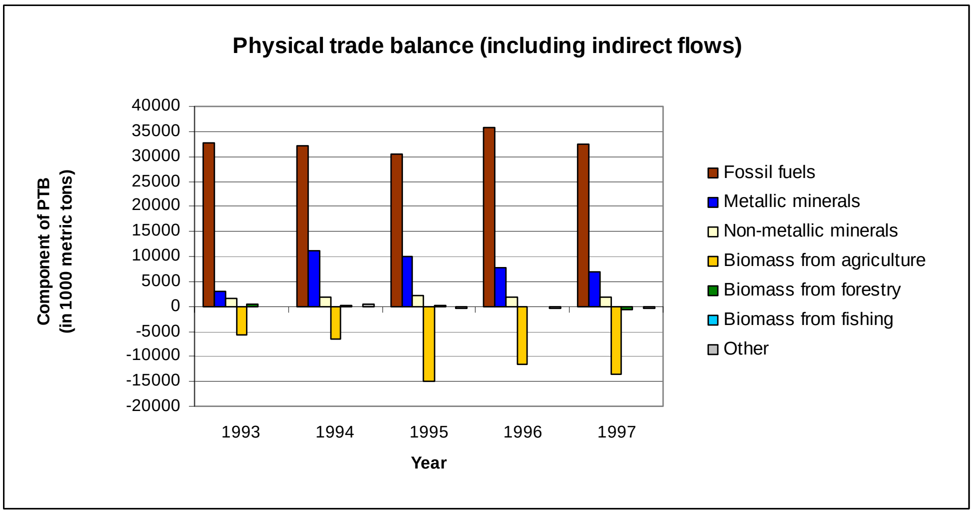
Figure 17: Physical trade balance



Source: own calculations.

A disaggregation of the physical trade balance by material categories shows that fossil fuels contribute most to the trade surplus. There exists a positive trade balance for most material categories but negative ones for biomass from agriculture and for some years for biomass from forestry and other products (consisting mainly of finished products).

Figure 18: Physical trade balance by material categories



Source: Own calculations.

The empirical results show, that the patters of material flows of the Hungarian Economy seem to move towards the characteristics of material flows in western European countries: increasing absolute and per capita flows by increasing efficiency.

7. Further development of material flow analysis

7.1 Physical Input-Output Tables (PIOT)

One of the next steps in the development of the methodology of material flow analysis could be the application of input-output techniques – known from economic input-output tables – to material flows. A physical input-output tables (PIOT) reports the flows between economic sectors of a country as well as flows between the economy and the environment in physical terms. PIOTs for several material flows have already been published for the Netherlands (Konijn *et al.* 1995, Konijn *et al.* 1997), Germany (Stahmer 2000, Stahmer *et al.* 1997, Stahmer *et al.* 1996), Denmark (Gravgaard Pederson 1999) and Finland (Mäenpää and Muukkonen 2001) and have been applied to an analysis of the import/export structure of the European Union (Giljum and Hubacek 2001). Theoretical and methodological considerations on physical input output tables can also be found in Weisz *et al.* (1999).

With the use of PIOTs the ‘black box’ of the national economy would be opened and material flows between economic sectors could be analysed. Main purposes for using PIOTs are the balancing and consistency checks, provision of a basis for modelling/analysis, providing a tool for estimating missing physical data, better understanding of underlying reasons for changes, calculation of material efficiencies per branch of production, and analysis of effects of policies (Eurostat 2001, p. 64).

There have also been examples to link monetary input-output tables with material flow data for a structural decomposition analysis, which allows an analysis of the effects of structural changes of the economy on material flows (Hinterberger *et al.* 1996, Hinterberger *et al.* ---; Hinterberger *et al.* 1999, Moll *et al.* 1998b, Moll *et al.* 1998a, Femia *et al.* 1999, Hoekstra and van den Bergh 2000, Hoffrén *et al.* 2001).

7.2 Quality of material flows

One of the most common criticisms on material flow analysis concerns the adding up of material flows each with very different inherent qualities and thus impacts on the environment. Therefore the need for a qualitative description of the analysed flows has been expressed (Lifset 2001, Kleijn 2001).

When describing the environmental impact of material flows one has to be aware that this impact depends on the material’s form and the material’s fate, that means where it ends up. For example, nitrogen absorbed in agricultural plant tissue may be good, whereas nitrogen in groundwater may be harmful (Matthews *et al.* 2000, p. 9).

A pilot scheme for characterising the quality of material flows has been introduced by Matthews *et al.* (2000, pp. 116). They characterise material flows by three ways: the mode of first release to the environment (M), quality categories such as physical and chemical characteristics (Q), and their velocity through the economy (Y). Table 4 presents an overview of this ‘MQV scheme.’

Table 4: Characterising material flows

Characterising material flows with the 'MQV scheme'		
Mode of first release categories (M)	Quality categories (Q)	Velocity categories (V)
- Flows becoming part of built infrastructure - Flows contained on land as solids (landfills, overburden) - Flows contained on land as liquids (tailing ponds) - Flows dispersed directly onto land (fertilisers, pesticides) - Flows discharged into water systems - Flows discharged into air - Flows that take many paths or no clearly defined path	- Flows that are biodegradable - Flows that replicate rapid continuous geologic processes - Flows that have not been chemically processed, but are chemically active (salts) or biologically hazardous (asbestos) - Flows that have undergone chemical processing (chemically active or not; fuel emissions, fertilisers, industrial chemicals) - Flows that are heavy metals, synthetic and persistent chemical compounds or radioactive	- Flows that exit the economy within two years - Flows which exit the economy in 3 to 30 years - Flows that stay within the economy for more than 30 years

Source: Modified from Matthews *et al.* (2000, pp 117).

Every disaggregated material flow of the database should be characterised by the criteria of such a classification scheme, so that one can search the database for flows with a specific combination of criteria. The application of such a scheme can also be used to weigh the flows according to chosen criteria.

Adriaanse *et al.*1997 (p. 6) presented two characteristics of material flows: the mobilisation (the spatial domain affected by a flow or the ability to reverse the impacts caused by a flow) and the potential for harm.

An overview of concepts describing the quality of flows is given by Fröhlich *et al.* ---. Possibilities for characterising material flows are manifold: verbal-argumentative description of the results, listing emissions and toxic substances, describing the ecological quality of certain flows, input-oriented accounting of toxic substances, or land use intensity of flows (Fröhlich *et al.* ---, pp. 51).

7.3 Material flows and land use

An interesting extension for further analysis is the linkage of material flows and resource consumption to land use patterns. Two major land use based indicators for ecological sustainability have been developed: the ecological footprint and the Sustainable Process Index (SPI). The ecological footprint measures the land area that has to be appropriated for the production and consumption of goods (within the investigated region or abroad). It accounts the land use for the following land categories: Agricultural land, pasture, forest, build-up land, water areas, and hypothetical areas for CO_2 sequestration. The used land areas are accounted by converting physical consumption (for the five categories food, housing, transportation, consumer goods, and services) to land areas with yields for materials (for example wood used for the production of paper) (Wackernagel and Rees 1996).

The SPI accounts the land area appropriated by economic processes. It is the relation of two areas: The area needed for embedding a process into the ecosphere and the area available per capita. In contrast to the ecological footprint it is more related to processes (for example the production of methanol for fuel use) than to consumption of goods (Krotscheck and Narodoslawsky 1996).

Giljum and Hubacek (2001) linked material flows to land use by applying input-output-techniques. They used a physical input-output-table of the European Union for the accounting of the land area within the European Union used for the production of export goods.

8. Conclusion

This report presents the results of a material flow analysis for Hungary for the years 1993-1997 as well as a discussion of the methods commonly used for such an analysis.

On a methodological level it is important to note that input indicators like the Total Material Requirement (TMR) and Direct Material input (DMI) cannot be added up internationally. The indirect flows associated to the imports of country *B* from country *A* would also be included in the input of country *A* as used (and unused) domestic extraction and therefore adding up input indicators would lead to double counting. Furthermore a significant share of the imports could be direct transit to other countries, especially in countries with important harbours ('Rotterdam effect,' Eurostat 2001, p. 24). Therefore consumption indicators which also take into account the exports of a country would be a more appropriate headline indicator for resource use. This point may be very important if production (especially of resource-intensive industrial branches) shifts from one country to another.

Several interesting conclusions can be drawn from the empirical results. The first one is, that material intensity of production in the Central Eastern European Countries (CEECs) analysed so far is higher than in western European countries. On the other hand material inputs per capita are lower in CEECs. Their material flow indicators seem to develop into the direction of western European countries – increasing efficiency with increasing per capita material inputs.

The question is, how economic development can take place without increasing burdens for nature. A decoupling can only be seen in relative terms – in material intensity per economic output. In most western industrialised countries absolute material flows and material flows per capita are increasing. But the goal of sustainability would make necessary an absolute reduction of material flows. The task would be to find a path of economic development without increasing material flows in absolute terms. Therefore, the rebound effect has to be taken into account. Technological innovations that increase resource efficiency do not automatically lead to decreasing absolute material flows. A sole focus on technology might mean turning a blind eye on environmental impacts and the general state of the environment. Lifestyles and their environmental impact will be another important leverage point for environmental policy. By understanding the relations between economic and technological development, changes in lifestyles, and their related material flows ways can be found for an absolute decoupling of economic development from material flows and resource use.

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Appendix

Appendix 1: Technical part

Domestic Extraction

Fossil Fuels

If not otherwise indicated, data on fossil fuels has been taken from the *Energy Statistics Yearbook* (UN 1997a, 2000a).

Hard coal

Two types of hard coal are included in this category: coking coal and other bituminous coal and anthracite (steam coal). Further slurries, middlings and other low-grade coal products, which cannot be classified according to the type of coal from which they are obtained, are included (UN 2000a, p. xi). Data for hard coal has been taken from *Industrial Commodity Statistics Yearbook* (UN 1999a).

Lignite/brown coal

This category includes two types of brown coal: lignite and sub-bituminous coal (UN 2000a, p. xi). As the data of *Energy Statistics Yearbook* corresponds with the one of the statistics (OECD/IEA 2000), where oil shale and tar sands produced and combusted directly are included in this category, they are included here too. Oil shale and tar sands used as inputs for other transformation processes are also included here (OECD/IEA 2000, p. I.9). The latter should be reported as unused domestic extraction associated with these transformation processes, so that mixing up of used and unused extraction occurs here for some extend. As the *Industrial Commodity Statistics Yearbook* (UN 1999a) and the *Minerals Yearbook (USGS* ---) do not state, what is included and excluded in their data, the data of the *Energy Statistics Yearbook* has been taken for this study.

Crude oil

Includes lease or field concentrate that is recovered from gaseous hydrocarbons in lease separation facilities, synthetic crude oil, mineral oils extracted from bituminous minerals and oils from coal liquefaction (UN 2000a, p. xiii). This may lead to double counting as the oils from bituminous sands and coal liquefaction may also be included in the reported coal extraction. It is not possible to separate this data from the statistical sources used.

Natural Gas

This category includes non-associated gas (from fields producing oil hydrocarbons in gaseous form) and associated gas (from field producing both liquid and gaseous hydrocarbons), as well as methane recovered from coalmines and sewage gas. It is measured as dry marketable production after purification and extraction of natural gas liquids and sulphur. Extraction losses and the amounts that have been re-injected, flared, and vented are excluded from the data on production.

In statistical sources the production of natural gas is reported in energetic units (terajoules TJ). These production data have therefore been converted into cubic meters by use of heat values (kilojoules per cubic meter) provided by the *Energy Statistics Yearbook* (UN 2000a, table V) for every country. In a last step the weight of natural gas has been calculated by using an assumed density of 0,85 kg/m^3 taken from Bringezu and Schütz (2001c, S. 15).

Natural gas liquids

Data is taken from OECD/IEA (2000).

Peat

Data is taken from the *Energy Statistics Yearbook* . Only peat used as fuel is included here.

Unused domestic extraction

Where available, ratios for unused domestic extraction (hidden flows) were taken from Bringezu and Schütz (2001c, pp. 15). It has to be stated, that these ratios are ratios for western European countries, which can only provide an estimation as the ratios differ markedly between countries, years, or different methods of extraction (for example, on shore ore offshore extraction).

Table 5: Ratios for hidden flows of fossil fuels.

Ratios of unused to used domestic extraction in ton per ton			
Hard coal	3.98	Natural gas	0.17[b]
Lignite	8.13[a]	Peat	0.25
Crude oil	0.08		

[a] Mean of reported ratios for Austria, Greece, Spain and Germany.
[b] Mean of reported total ratios for Denmark, Spain, Italy, Netherlands, UK, Austria and Germany.

Source: Bringezu and Schütz (2001c, pp. 15).

Minerals and ores

If not indicated otherwise, data is taken from the *Industrial Commodity Statistics Yearbook* (UN 1999a).

Metal ores

Data was taken from *Minerals Yearbook* (USGS ---) and *Industrial Commodity Statistics Yearbook* (UN 1999a). If different weights were reported, data was taken from the *Industrial Commodity Statistics Yearbook*. If available from the *Minerals Yearbook* the weight of the crude metal ores ("run of mine") has been accounted. If the weight of metal ore production was not reported, the weight of the reported metal content had to be converted into the weight of metal ore.

This had to be done because according to the suggestion of Eurostat (2001, p. 46) the crude metal ores are accounted as direct (used) material inputs. As for the most ores the production is reported in the weight of the metal content of the ore the weight of the crude ore (including ancillary flows) had to be calculated. In a second step the unused domestic flows (for example, overburden) have been calculated.

Therefore the weight of the metal ore has first been multiplied with ancillary mass factors taken from Mündl and Scharnagl (1998, p. 326) to derive the weight of the crude ore. If the metal production was recorded in statistics as production of crude ore the reported weight was used for calculating unused flows.

For calculating unused flows the weight of the metal ore (derived by the first step or directly reported in statistics) has been multiplied with unused flow ratios taken from Bringezu and Schütz (2001c, p. 24) or Adriaanse *et al.* (1997). The following factors and ratios have been used:

Table 6: Ancillary mass and unused flow factors for metal ores

Metal/ore	Ancillary mass factors (in tons per ton) [a]	Unused flow factors (in tons per ton) [b]
Bauxite	r	0.48
Gallium	---	---
Manganese	0.14	0.1
Vanadium	127.7	0.1
Uranium	98500	1.9
Gold	350000	0.1

r: Weight of crude ore was reported in statistics.

Sources: [a] from Mündl and Scharnagl (1998, p. 326, data for 1993 has been used); [b] from Bringezu and Schütz (2001c, p. 24), factor for bauxite from Adriaanse et al. (1997, p. 61)

No unused flows have been accounted for gallium production as this metal is classified as a by-product of other mining activities (Adriaanse *et al.* 1997, p. 41).

Clays

The *Industrial Commodity Statistics Yearbook* provides data for total clay production and for certain clays (for example, kaolin) separately. The amount for the category "other clays" has been calculated by subtracting the data for certain types of clay recorded separately from the data for total clay production.

Peat

Only peat for agricultural use is recorded in this category

Unused domestic extraction of minerals

Coefficients for hidden flows have been taken – where available – from Bringezu and Schütz (2001c, p. 19) and are as follows:

Table 7: Ratios of unused flows of minerals.

Ratios of unused to used domestic extraction in tons per ton			
Crushed rock aggregates	0.23	Fuller's Earth	0.0105[a]
Sand and gravel	0.14	Kaolin	1.175[a]
Dimension stone	0.23	Other clays	0.25[b]
Slate	0.16[a]	Natural phosphates	12.02
Diatomite	1.1[a]	Potash salts	4.65[a]
Feldspar	0.006[a]	Salts	0.049[a]
Silica sand	0.00609[a]	Barytes	0.57[a]
Talc and steatite	0.45	Flourspar	1.395[a]
Peat	0.25	Graphite	0.755[a]
Limestone and dolomite	0.33	Gypsum, crude	0.1

[a] Mean of values for Germany.
[b] Value for EU countries.

Sources: Bringezu and Schütz (2001c, p. 19); ratio for gypsum from Mündl and Scharnagl (1998, p. 328).

The ratio for dimension stone was also used for dolomite, granite, porphyry and sandstone. No ratio for perlite could have been found in the literature.

Biomass from agriculture

Unless indicated otherwise data has been taken from the data homepage of the FAO (http://faostat.fao.org/default.htm or http://apps.fao.org). The ratio for unused flows of agricultural commodities of 0.62 tons per ton is taken from Bringezu and Schütz (2001c, p. 22).

Biomass from grazing has been estimated as follows. The numbers of animal livestock in heads per year have been taken from the FAO homepage. These numbers have been multiplied with an estimated annual biomass consumption per head for each kind of animal, based on factors for daily consumption in dry matter from Niels Schulz and Christof Amann (personal communication). The water content of the resulting annual biomass consumption has then been corrected from 0% (dry matter) to 15%. The 15% meet the requirements of the Eurostat guide for a "standardised water content" (Eurostat 2001, p.45). From the resulting annual consumption the fodder reported in the food balance sheets of the FAO statistics has been deducted after the values for fodder have been corrected from fresh weight to 15% water content and reduced by the estimated amount of fodder for pigs. The amount of fodder for pigs has been estimated by assuming a daily consumption in dry matter of 1 kg per head (own assumption). The following table presents the sources for fresh weight water contents of fodder items:

Table 8: Fresh weight water contents of fodder items

	Water content (in %)	Source
Cereals	14	Schandl et al. (2002), p. 45.
Starchy roots	83	Schandl et al. (2002), p. 45, mean of values for roots and tubers.
Sweeteners	...	No correction of water content accounted.
Pulses	12	Brockhaus (1971), p. 697.
Oilcrops	57	Schandl et al. (2002), p. 45, mean of values for vegetables.
Vegetables	57	Schandl et al. (2002), p. 45, mean of values for vegetables.
Fruit	85	Schandl et al. (2002), p. 45, mean of values for fruits.
Milk	87	Brockhaus (1971), p. 697.
Eggs	73	Brockhaus (1971), p. 697.
Fish	42	Brockhaus (1971), p. 697.
Maize for forage and silage	73	Niels Schulz, personal communication
Grasses for forage and silage	85	Niels Schulz, personal communication
Clover for forage and silage	85	Niels Schulz, personal communication
Leguminous for forage and silage	12	Brockhaus (1971), p. 697.
Turnips for fodder	83	Schandl et al. (2002), p. 45, mean of values for roots and tubers.
Vegetables and roots for fodder	57	Schandl et al. (2002), p. 45, mean of values for vegetables.

The weights of biomass for forage and silage and fodder (category by-product of harvest) has also been corrected from reported fresh weights to a water content of 15%.

Biomass from forestry

Unless indicated otherwise data has been taken from the data homepage of the FAO (http://faostat.fao.org/default.htm or http://apps.fao.org). As the production of raw materials from forestry is reported in cubic meters it had to be converted with the following factors given by FAO (2001, p. xxix):

Table 9: Weights and volumes of roundwood

Ratio between volume and weight for roundwood in cubic meters per metric ton		
	Coniferous	Non-Coniferous
Wood fuel	1.60	1.33
Saw logs and veneer logs	1.43	1.25
Pulpwood	1.54	1.33
Other industrial roundwood	1.43	1.25

Source: FAO (2001, p. xxix).

The ratio of unused flows has been taken from Adriaanse *et al*. (1997, p. 64). The reported ratio of 0.45 tons per ton of roundwood for the USA was applied to all forestry raw materials reported in this study.

Biomass from fishing

Unless indicated otherwise data has been taken from the data homepage of the FAO (http://faostat.fao.org/default.htm or http://apps.fao.org). The ratio of the hidden flows (0.25 tons per ton) has been taken from Bringezu and Schütz (2001c, p. 14), who refer to a study of Greenpeace estimating, that 25% of the fish catch are discarded on board.

Biomass from hunting and other activities

Other activities refers to honey, gathering of mushrooms, berries, herbs, etc. No data could be found for these two categories.

Excavation and dredging

Material flows by excavation for infrastructure have been estimated as follows: the *UN Statistical Yearbook* gives the share of GDP for construction activities for the years 1993, 1994 and 1995. The absolute value added by construction activities (in constant 1990 US dollars) has been calculated by using GDP data from the *UN Statistical Yearbook* and converted into ECU by use of exchange rates provided by the *International Financial Statistics* of the International Monetary Fond. Value added by construction activities for the years 1996 and 1997 have been estimated by using volume indices reported by the *Statistical Yearbook of Hungary* (Hungarian Central Statistical Office 1999) and taking the year 1995 as basis.

These values added have been multiplied with excavation coefficients (in tons of excavation per million ECU value added by construction activities) taken from Bringezu and Schütz (Bringezu and Schütz 2001c, p. 13). For the years 1993-1996 the weighted averages of Germany, the Netherlands, Austria and Finland reported there have been taken. For 1997 the coefficient of the year 1996 has been used.

No material flows for dredging have been included.

Imports and Exports

Imports and exports are classified according to the *Standard International Trade Classification Revision 3 (SITC Rev. 3)* that is used by the *UN International Trade Statistics Yearbook (UN-ITSY).* This classification differs from the classification suggested by Eurostat (2001). There imports and exports should allow a distinction between raw materials, semi-manufactures and manufactured goods and within each of these three groups a distinction – as far as possible – between material categories (fossil fuels, minerals, ores, bio-mass). Therefore the import/export data would have to be re-arranged to follow these conditions. Eurostat (2001) and Bringezu and Schütz (2001c) provide consistent tables for re-arranging import/export data on the basis of the *Harmonised System (HS)/Combined Nomenclature (CN)*, the trade classification system used by the European Union. For the reallocation of data the original data used for this study would first have to be converted from *SITC Rev. 3* into *HS* and than be re-grouped again. This was not possible during the available time for this study. The classification numbers of the *HS* have only been allocated to imports/exports of raw materials and semi-manufactures for which indirect flows have been used or the *HS* classification was stated in Bringezu and Schütz (2001c). For all other commodities mentioned in Eurostat (2001, p. 81) the allocation to the *HS* classification has not been done.

For the conversion of commodities from *SITC Rev. 3* . to *HS* a table found at

http://www.macalester.edu/research/economics/PAGE/HAVEMAN/Trade.Resources/Concordances/FromHS/NBER/hts.sitc3

has been used. Data on imports has been taken from the Trade Analysis System (PC-TAS) from the United Nations Conference on Tariffs and Trade (UNCTAD) and the World Trade Organisation (WTO) (UCTAD and WTO ---).

Indirect flows associated to imports and exports

If not stated otherwise the ratios for indirect flows associated to imports and exports have been taken from Bringezu and Schütz (2001c, p. 28) and if not available there, from Bringezu (2000, p. 223). No assumptions on the shares of recycled materials in imported or exported semi-factors have been made. Imports and exports have, therefore, – if not explicitly reported otherwise in trade statistics – been treated as if consisting of 100% primary materials.

Indirect flows have been estimated – as far as ratios have been available – for the following imported material categories: Agricultural raw materials, forestry raw materials, fish, agricultural plant products, agricultural animal products, semi-manufactures from forestry, finished products from forestry, animals as products, (non)-metallic minerals (raw materials), semi-manufactures from fossil fuels, semi-manufactures from (non)-metallic minerals.

In Bringezu (2000) Material-Input-(MI)-Coefficients are reported, which document the total necessary material input (in tons) per ton of commodity. The MI-coefficients of biotic products consist of two parts: indirect flows of biotic materials and erosion. The MI-coefficients consist of only one part, indirect flows of abiotic materials. As the MI-Coefficients include the weight of the commodity (Schmidt-Bleek *et al.* 1998, p.27, Schmidt-Bleek 1998, p. 135) the MI-coefficients for materials had to be reduced by *1*. The indirect flows associated to imports of biotic materials do not include soil erosion. This follows the methodology of Eurostat (2001, p. 49) where soil erosion is not included in the final indicators.

For some commodities the table reports a MI-coefficient of 1 ton of indirect flows per ton of commodity. It is explained there that in that case no specific information was available on indirect flows for that commodity and therefore the weight of the commodity itself has been accounted as MI. In that case no indirect flow has been used in this study (shown by *0* in the spreadsheets) as the weight of the commodity itself is already accounted for as direct input.

Indirect flow ratio of biotic materials of bananas is based on Giljum (1999, personal communication). Indirect flow ratio of erosion for bananas is based on Bringezu (2000).

Indirect flows of exports

For accounting indirect flows associated to exports the same ratios used for accounting indirect flows associated to imports have been used. These factors are based on imports of various countries to Germany or the European Union and therefore can only provide a rough estimation of the indirect flows associated to exports. No indirect flows have been calculated for finished products, as – due to lack of data - no indirect flows on imported finished goods have been reported in the literature.

Electricity

According to Eurostat the fuels required abroad to produce imported electricity should be counted as indirect floes associated to the imports of electricity (Eurostat 2001, p. 24). A ratio for indirect flows of 1.58 tons per MWh (representing the average material intensity for European OECD countries) has been taken from Bringezu and Schütz (2001c, p. 45).

Data on imports and exports of electricity has been taken from the *Energy Statistics Yearbook* , Table 35.

Transportation

Indirect flows of imported goods do not include the consumption of materials used for transportation (for example, fuels).

GDP and Population Data

Unless indicated otherwise GDP data has been taken from the *UN Statistical Yearbook* and population data has been taken from the FAO homepage.

Appendix 2: Data summary

Overview and indicators
(in 1000 metric tons, GDP in millions US dollars at constant 1990 prices, population in thousands)
Classification of material categories of demestic extraction taken from EUROSTAT/European Commission 2001, of imports from SITC.

		1993	1994	1995	1996	1997
Domestic extraction						
1.1.	Fossil fuels	21519	21288	22356	22573	22574
1.2.	Minerals and ores	20275	23509	27021	24052	26876
1.2.1.	Ores	5030	4482	3038	3022	2701
1.2.2.	Industrial minerals	126	986	1855	1717	2283
1.2.3.	Construction minerals	9100	11155	14996	13635	14688
1.2.4	Ind. and constr. minerals	6019	6886	7132	5678	7204
1.3.	Biomass	26031	27456	27046	27834	30276
1.3.1.	Biomass from agriculture	22607	24003	23728	25043	27029
1.3.2.	Biomass from forestry	3401	3428	3295	2770	3226
1.3.3.	Biomass from fishing	23	24	23	21	22
1.3.4.	Biomass from hunting	...	...	...	...	...
1.3.5.	Biomass from other activities	...	...	...	...	...
	Total domestic extraction	**67825**	**72253**	**76423**	**74459**	**79726**
Unused domestic extraction						
1.1.	Fossil fuels	122805	119729	122924	127868	131220
1.2.	Minerals and ores	10082	10796	8203	7445	7889
1.2.1.	Ores	6910	7085	3902	3763	3612
1.2.2.	Industrial minerals	34	35	45	37	137
1.2.3.	Construction minerals	1274	1562	2099	1909	2056
1.2.4	Ind. and constr. minerals	1865	2114	2156	1736	2083
1.3.	Biomass	15553	16431	16200	16779	18215
1.3.1.	Biomass from agriculture	14016	14882	14711	15527	16758
1.3.2.	Biomass from forestry	1531	1543	1483	1247	1452
1.3.3.	Biomass from fishing	6	6	6	5	6
1.3.4.	Biomass from hunting	...	...	...	...	...
1.3.5.	Biomass from other activities	...	...	...	...	...
	Excavation	6918	7121	6404	5971	6461
	Total unused domestic extraction	**155358**	**154076**	**153732**	**158063**	**163784**
Imports						
2.1.	**Raw materials**					
2.1.1.	Fossil fuels	14149	14092	14156	16235	15331
2.1.2.	Minerals					
2.1.2.1.	Metallic minerals	5	2185	2122	1544	381
2.1.2.2.	Non-metallic minerals	894	792	819	990	976
2.1.3.	Biomass					
	Agriculture	461	760	458	472	477
	Forestry	319	150	205	202	260
	Fish	7	7	7	7	8
2.1.4.	Secondary raw materials	53	16	6	8	74
2.2.	**Semi-manufactured products**					
2.2.1.	From fossil fuels	845	982	921	1060	527
2.2.2.	From minerals					
2.2.2.1.	From metallic minerals	615	707	955	818	1190
2.2.2.2.	From non-metallic minerals	262	391	411	351	454
2.2.3.	From biomass					
	Forestry	473	557	603	582	624
2.3.	**Finished products**					
2.3.1.	Forestry	400	478	465	503	647
2.4.	**Other products**					
2.4.2.1	Agricultural plant products	831	905	939	832	878
2.4.2.2	Agricultural animal products	106	170	97	96	107
2.4.2.3	Animals as products	3	5	4	4	5
	Other imports	2946	3525	3234	3407	4146
	Total Imports	**22369**	**25721**	**25403**	**27112**	**26086**
Indirect flows associated to imports						
2.1.	**Raw materials**					
2.1.1.	Fossil fuels	16468	16793	14490	17482	15787
2.1.2.	Minerals					
2.1.2.1.	Metallic minerals	2	4018	3783	2777	684
2.1.2.2.	Non-metallic minerals	699	695	677	935	983
2.1.3.	Biomass					
	Agriculture	151	483	168	173	167
	Forestry	145	68	93	91	117
	Fish	2	2	2	2	2
2.1.4.	Secondary raw materials					
2.2.	**Semi-manufactured products**					
2.2.1.	From fossil fuels	1778	2083	1959	2120	979
2.2.2.	From minerals					
2.2.2.1.	From metallic minerals	9206	10877	11026	10390	12015
2.2.2.2.	From non-metallic minerals	827	1273	1406	1354	1514
2.2.3.	From biomass					
	Forestry	1123	1370	1517	1241	1251
2.3.	**Finished products**					
2.3.1.	Forestry	584	697	676	732	930
2.4.	**Other products**					
2.4.2.1	Agricultural plant products	866	667	572	103	120
2.4.2.2	Agricultural animal products	986	1603	866	593	1157
2.4.2.3	Animals as products	1	1	1	1	1
	Other imports					
	Total indirect flows associated to imports	**32838**	**40631**	**37236**	**37994**	**35708**

Exports

2.1.	**Raw materials**					
2.1.1.	Fossil fuels	41	225	38	59	48
2.1.2.	Minerals					
2.1.2.1.	Metallic minerals	278	0	20	0	59
2.1.2.2.	Non-metallic minerals	591	647	713	1039	1280
2.1.3.	Biomass					
	Agriculture	1253	1847	4328	1583	3060
	Forestry	1050	1090	1073	997	1319
	Fish	2	3	3	3	3
2.1.4.	Secondary raw materials					
2.2.	**Semi-manufactured products**					
2.2.1.	From fossil fuels	150	213	347	301	42
2.2.2.	From minerals					
2.2.2.1.	From metallic minerals	1179	1430	1677	1656	1504
2.2.2.2.	From non-metallic minerals	140	139	65	160	191
2.2.3.	From biomass					
	Forestry	115	135	146	146	193
2.3.	**Finished products**					
2.3.1.	Forestry	215	367	433	522	671
2.4.	**Other products**					
2.4.2.1	Agricultural plant products	727	934	1559	1224	1212
2.4.2.2	Agricultural animal products	312	322	340	441	464
2.4.2.3	Animals as products	0	0	0	0	0
	Other exports	3065	3141	3492	3673	4617
	Total Exports	**9117**	**10494**	**14234**	**11806**	**14663**

Indirect flows associated to exports

2.1.	**Raw materials**					
2.1.1.	Fossil fuels	23	1106	18	101	21
2.1.2.	Minerals					
2.1.2.1.	Metallic minerals	181	0	13	0	39
2.1.2.2.	Non-metallic minerals	146	156	169	241	288
2.1.3.	Biomass					
	Agriculture	819	1410	3522	1053	1551
	Forestry	370	419	422	364	519
	Fish	0	1	1	1	1
2.1.4.	Secondary raw materials					
2.2.	**Semi-manufactured products**					
2.2.1.	From fossil fuels	222	336	557	534	7
2.2.2.	From minerals					
2.2.2.1.	From metallic minerals	5299	5325	6257	6090	5653
2.2.2.2.	From non-metallic minerals	199	204	96	309	362
2.2.3.	From biomass					
	Forestry	524	652	675	663	890
2.3.	**Finished products**					
2.3.1.	Forestry	248	453	524	646	834
2.4.	**Other products**					
2.4.2.1	Agricultural plant products	226	292	658	551	466
2.4.2.2	Agricultural animal products	5856	6264	7669	9028	9750
2.4.2.3	Animals as products	0	0	0	0	0
	Other exports					
	Total indirect flows associated to exports	**14114**	**16618**	**20580**	**19580**	**20380**

Population (in thousand)	10281	10256	10227	10193	10156
GDP (in million 1990 US dollars)	30379	31274	31738	32690	34193

Indicators

Direct Material Input (DMI) (in 1000 metric tons)	90194	97974	101826	101571	105812
Total Material Requirement (TMR) (in 1000 metric tons)	278390	292680	292794	297628	305304
Domestic Material Consumption (DMC) (in 1000 metric tons)	81077	87480	87591	89765	91149
Total Material Consumption (TMC) (in 1000 metric tons)	255159	265569	257979	266242	270261
Physical Trade Balance (PTB) (in 1000 metric tons)	13252	15227	11169	15306	11423
Physical Trade Balance (PTB') (including indirect flows, in 1000 metric tons)	31976	39240	27825	33720	26751
DMI per Capita (in tons per capita)	9	10	10	10	10
TMR per Capita (in tons per capita)	27	29	29	29	30
DMC per Capita (in tons per capita)	8	9	9	9	9
TMC per Capita (in tons per capita)	25	26	25	26	27
PTB per capita (in kilogramme per capita)	1289	1485	1092	1502	1125
PTB' per capita (in kilogramme per capita)	3110	3826	2721	3308	2634
DMI per GDP (in tons per million 1990 US dollar)	2969	3133	3208	3107	3095
TMR per GDP (in tons per million 1990 US dollar)	9164	9359	9225	9105	8929
DMC per GDP (in tons per million 1990 US dollar)	2669	2797	2760	2746	2666
TMC per GDP (in tons per million 1990 US dollar)	8399	8492	8128	8144	7904
PTB per GDP (in tons per million 1990 US dollar)	436	487	352	468	334
PTB' per GDP (in tons per million 1990 US dollar)	1053	1255	877	1032	782
PTB in % of impoprts	59	59	44	56	44
PTB' in % of imports (including indirect flows)	58	59	44	52	43

TMR per capita by material categories (in metric tons per capita)

	1993	1994	1995	1996	1997
Fossil fuels	17,27	17,06	17,29	18,38	18,36
Metallic minerals	2,12	2,86	2,43	2,19	2,03
Non-metallic minerals	2,05	2,52	3,09	2,78	3,19
Biomass from agriculture	3,89	4,24	4,06	4,20	4,60
Biomass from forestry	0,76	0,80	0,81	0,71	0,83
Biomass from fish	0,00	0,00	0,00	0,00	0,00
Excavation	0,67	0,69	0,63	0,59	0,64
Other	0,29	0,35	0,32	0,34	0,42
Total	**27,06**	**28,53**	**28,62**	**29,19**	**30,05**

TMR per capita by material categories (in percent)

	1993	1994	1995	1996	1997
Fossil fuels	63,82	59,79	60,41	62,96	61,08
Metallic minerals	7,82	10,03	8,48	7,50	6,74
Non-metallic minerals	7,58	8,85	10,80	9,53	10,61
Biomass from agriculture	14,38	14,86	14,19	14,40	15,30
Biomass from forestry	2,81	2,81	2,82	2,45	2,75
Biomass from fish	0,02	0,02	0,01	0,01	0,01
Excavation	2,49	2,43	2,19	2,01	2,12
Other	1,08	1,21	1,11	1,15	1,38
Total	**100,00**	**100,00**	**100,00**	**100,00**	**100,00**

DMI per capita by material categories (in metric tons per capita)

	1993	1994	1995	1996	1997
Fossil fuels	3,55	3,55	3,66	3,91	3,78
Metallic minerals	0,55	0,72	0,60	0,53	0,42
Non-metallic minerals	1,63	2,00	2,52	2,24	2,59
Biomass from agriculture	2,33	2,52	2,47	2,59	2,81
Biomass from forestry	0,45	0,45	0,45	0,40	0,47
Biomass from fish	0,00	0,00	0,00	0,00	0,00
Other	0,29	0,35	0,32	0,34	0,42
Total	**8,81**	**9,58**	**10,01**	**10,01**	**10,49**

DMI per capita by material categories (in percent)

	1993	1994	1995	1996	1997
Fossil fuels	40,32	36,99	36,57	39,07	36,07
Metallic minerals	6,24	7,50	5,97	5,28	4,01
Non-metallic minerals	18,50	20,88	25,16	22,38	24,72
Biomass from agriculture	26,51	26,29	24,64	25,91	26,74
Biomass from forestry	5,07	4,69	4,46	3,98	4,46
Biomass from fish	0,04	0,04	0,03	0,03	0,03
Other	3,31	3,60	3,16	3,35	3,96
Total	**100,00**	**100,00**	**100,00**	**100,00**	**100,00**

DMC by material categories (in 1000 metric tons)

	1993	1994	1995	1996	1997
Fossil fuels	36322	35924	37047	39509	38343
Metallic minerals	4193	5944	4418	3727	2709
Non-metallic minerals	15670	19424	24436	21171	24134
Biomass from agriculture	21716	22739	18999	23199	23758
Biomass from forestry	3212	3020	2917	2392	2574
Biomass from fish	29	28	27	25	28
Other	-65	400	-253	-258	-396
Total	**81077**	**87480**	**87591**	**89765**	**91149**

DMC by material categories (in percent)

	1993	1994	1995	1996	1997
Fossil fuels	45	41	42	44	42
Metallic minerals	5	7	5	4	3
Non-metallic minerals	19	22	28	24	26
Biomass from agriculture	27	26	22	26	26
Biomass from forestry	4	3	3	3	3
Biomass from fish	0	0	0	0	0
Other	0	0	0	0	0
Total	**100**	**100**	**100**	**100**	**100**

TMC by material categories (in 1000 metric tons)

	1993	1994	1995	1996	1997
Fossil fuels	177127	173087	175845	186343	186300
Metallic minerals	14832	22598	16860	14568	13330
Non-metallic minerals	20023	24743	30555	26592	30257
Biomass from agriculture	30835	32410	23468	28965	30194
Biomass from forestry	5453	5175	5066	4030	4081
Biomass from fish	36	35	34	31	35
Other	6853	7521	6151	5713	6064
Total	**255159**	**265569**	**257979**	**266242**	**270261**

TMC by material category (in percent)

	1993	1994	1995	1996	1997
Fossil fuels	69	65	68	70	69
Metallic minerals	6	9	7	5	5
Non-metallic minerals	8	9	12	10	11
Biomass from agriculture	12	12	9	11	11
Biomass from forestry	2	2	2	2	2
Biomass from fish	0	0	0	0	0
Other	3	3	2	2	2
Total	**100**	**100**	**100**	**100**	**100**

Share of lignite on TMR (in percent)

	1993	1994	1995	1996	1997
Domestic extraction	5,22	4,82	4,98	5,10	5,11
Unused domestic extraction	42,44	39,20	40,51	41,49	41,51
Imports	0,38	0,23	0,14	0,19	0,15
Indirect flows associated to imports	2,58	1,58	0,96	1,31	1,05

Domestic extraction (in percent)

		1993	1994	1995	1996	1997
1.1.	Fossil fuels	32	29	29	30	28
1.2.	Minerals and ores	30	33	35	32	34
1.2.1.	Ores	7	6	4	4	3
1.2.2.	Industrial minerals	0	1	2	2	3
1.2.3.	Construction minerals	13	15	20	18	18
1.2.4	Ind. and constr. minerals	9	10	9	8	9
1.3.	Biomass	38	38	35	37	38
1.3.1.	Biomass from agriculture	33	33	31	34	34
1.3.2.	Biomass from forestry	5	5	4	4	4
1.3.3.	Biomass from fishing	0	0	0	0	0
1.3.4.	Biomass from hunting	...	...	...	...	...
1.3.5.	Biomass from other activities	...	...	...	...	...
	Total	**100**	**100**	**100**	**100**	**100**

Unused domestic extraction (in percent)

		1993	1994	1995	1996	1997
1.1.	Fossil fuels	79	78	80	81	80
1.2.	Minerals and ores	6	7	5	5	5
1.2.1.	Ores	4	5	3	2	2
1.2.2.	Industrial minerals	0	0	0	0	0
1.2.3.	Construction minerals	1	1	1	1	1
1.2.4	Ind. and constr. minerals	1	1	1	1	1
1.3.	Biomass	10	11	11	11	11
1.3.1.	Biomass from agriculture	9	10	10	10	10
1.3.2.	Biomass from forestry	1	1	1	1	1
1.3.3.	Biomass from fishing	0	0	0	0	0
1.3.4.	Biomass from hunting	...	...	...	...	...
1.3.5.	Biomass from other activities	...	...	...	...	...
	Excavation	4	5	4	4	4
	Total	**100**	**100**	**100**	**100**	**100**

Unused domestic extraction (in percent of TMR and in relation to used domestic extraction)

	1993	1994	1995	1996	1997
Unused/used domestic extraction	2,29	2,13	2,01	2,12	2,05
Unused domestic extraction/TMR (in %)	55,81	52,64	52,51	53,11	53,65

Relation of TMR and DMI

	1993	1994	1995	1996	1997
DMI/TMR (in percent)	32	33	35	34	35
TMR-DMI (in 1000 metric tons)	188196	194707	190968	196057	199492

Share of imports on DMI and TMR (in percent)

	1993	1994	1995	1996	1997
Import/DMI	25	26	25	27	25
Imports + indirect flows/TMR	20	23	21	22	20

Selected imports (in percent of total imports)

	1993	1994	1995	1996	1997
Imports of fossil fuels	63	55	56	60	59
Other imports	13	14	13	13	16

Changes in variables (1993=100)

	1993	1994	1995	1996	1997
GDP	100	103	104	108	113
GDP/capita	100	103	105	109	114
TMR	100	105	105	107	110
TMR/capita	100	105	106	108	111
TMR/GDP	100	102	101	99	97
DMI	100	109	113	113	117
DMI/capita	100	109	113	114	119
DMI/GDP	100	106	108	105	104
DMC	100	108	108	111	112
DMC/capita	100	108	109	112	114
DMC/GDP	100	105	103	103	100
TMC	100	104	101	104	106
TMC/capita	100	104	102	105	107
TMC/GDP	100	101	97	97	94
PTB	100	115	84	116	86
PTB/capita	100	115	85	117	87
PTB/GDP	100	112	81	107	77
PTB'	100	123	87	105	84
PTB'/capita	100	123	87	106	85
PTB'/GDP	100	119	83	98	74
Direct input per capita of fossil fuels	100	100	103	110	107
Direct input per capita of metallic minerals	100	131	109	96	77
Direct input per capita of non-metallic minerals	100	123	155	137	159
Direct input per capita of biomass from forestry	100	108	106	111	120
Direct input per capita of biomass from agriculture	100	101	100	89	105
Direct input per capita of biomass from fishery	100	107	102	97	105

Import structure (Imports in 1000 metric tons)

	1993	1994	1995	1996	1997
Raw materials	15888	18002	17774	19457	17507
Semi-manufactured products	2195	2636	2890	2812	2795
Finished products	4286	5083	4739	4843	5783

Export structure (Exports in 1000 metric tons)

	1993	1994	1995	1996	1997
Raw materials	3214	3811	6176	3681	5769
Semi-manufactured products	1584	1917	2235	2264	1930
Finished products	4319	4765	5824	5861	6964

PTB' (including indirect flows, in 1000 metric tons)

	1993	1994	1995	1996	1997
Imports	55207	66352	62640	65106	61794
Exports	23231	27111	34814	31386	35043
PTB'	31976	39240	27825	33720	26751
PTB' in % of Imports	58	59	44	52	43

PTB' by material categories (in 1000 metric tons, including indirect flows)

	1993	1994	1995	1996	1997
Fossil fuels	32803	32070	30565	35902	32506
Metallic minerals	2892	11031	9920	7783	7017
Non-metallic minerals	1606	2006	2271	1881	1806
Biomass from agriculture	-5788	-6476	-14971	-11604	-13592
Biomass from forestry	521	204	287	13	-596
Biomass from fish	7	5	5	5	7
Other	-65	400	-253	-258	-396