Technical report No 55

Total material requirement of the European Union

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Foreword

The first edition of the regular indicator report of the European Environment Agency, *Environmental signals 2000*, contains a chapter on a new aggregated indicator for overall pressures on the environment: Total material requirement (TMR). The aim of this chapter is to explore the usefulness of such an indicator to support policy-making by showing an elaborated example. Although the EEA uses the principle that all its information must be gathered by its member countries, in this case an exemption was made, and the Wuppertal Institute was asked to process Eurostat's and its own data to come up with a first calculation of the total material requirement indicator for the European Union. More detailed, but comparable data are also available from the few countries (the Netherlands, Finland, Germany) which made their own calculations.

In this report, all outcomes of the first calculation of TMR for the EU are included. In fact it has a similar aim as the TMR chapter in the *Environmental signals 2000* report: to stimulate the discussion on the usefulness of total material requirement and related indicators for policy-making by showing concrete results.

The EEA hopes that this report will stimulate many users to have a closer look at the aggregates, and to think of possible changes for environmental and other policies.

For those who need to go into the details of the calculation the EEA has produced a separate technical report (EEA technical report No 56), which describes the methodology in detail.

Peter Bosch

Summary

This report contains the results of the first calculation of the total material requirement of the European Union comprising both extraction from domestic sources and imports along with their hidden flows. Extraction of resources within EU-15 declined from 1985 to 1997 by 13 %. Domestic extraction tends to use resources with higher resource efficiency. Requirements for foreign resources from outside EU-15 increased from 1995 to 1997 by 11 %. Imported metals, minerals and agricultural products are associated with higher hidden flows per commodity than domestic production, indicating a relatively higher burden to the environment of foreign countries. Foreign TMR is significantly influenced by EU-15 demand for luxury and precious commodities. Direct input of primary materials (DMI) per capita was reduced by 9 % at the beginning of the 1990s but slightly increased afterwards. This led to a relative decoupling of GDP and DMI in EU-15 as a whole between 1988 and 1997. Direct material productivity of EU-15 was increased by 28 %. Whereas in most Member States economic growth had been associated with increased DMI, a reduced dependence on direct material inputs could be recorded for Finland, France, Italy, Sweden and the United Kingdom. Based on available data, total material productivity of EU-15 could be calculated for the period 1995 to 1997. No significant decoupling of TMR and GDP occurred during these three years.

1. The policy context

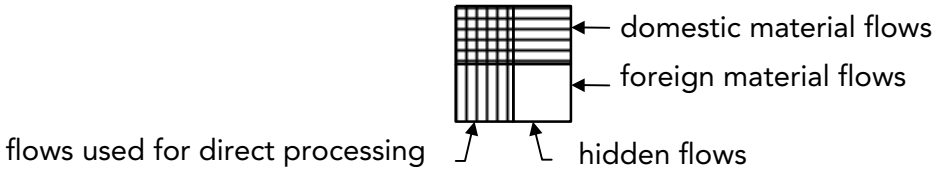
As stated in the conclusions of the meeting of the Heads of State or Government of the European Union countries in Helsinki in December 1999 (European Council 1999), a net reduction in the use of natural resources is needed to bring economic growth in line with the Earth's carrying capacity. To this end, economic performance and requirements for natural resources must be decoupled. In other words, resource efficiency should be increased. As outlined by the EEA before (European Environment Agency, 1999a,b), this strategy is regarded as a prerequisite for an absolute delinking of economic growth and resource consumption. In Helsinki in July 1999, the environmental ministers of the EU agreed that targets and timetables should be set, where appropriate, for improving eco-efficiency in the different sectors and the development monitored with appropriate indicators (*Source:* http://presidency.finland.fi/netcomm/eventcal/showarticle.asp?intNWSAID=2370&intIGID=6&tapah_id=84).

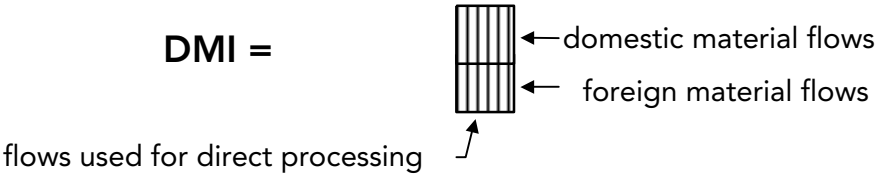
As a proposal for target development, the factor 4 to 10 concept has often been mentioned (see European Environment Agency, 1999b, Gardener and Sampat, 1998) since its formulation by Schmidt-Bleek (1993) and Weizsäcker et al. (1995). In order to reduce global resource extraction by half, industrial countries should increase the efficiency of overall primary resource requirements of energy and materials in the next 30 to 50 years by 4 to 10 times. The factor 4 to 10 goal had been noted by the OECD environmental ministers in 1996 and was adopted by the Ungass in 1997. In some of the Member States it has stimulated political debate, for example, in Germany, the Netherlands and Sweden it has become part of political programmes, and in Austria and Finland it is subject to specific research (see especially Nordic Council of Ministers: 'Factors 4 and 10 in the nordic countries'). Within the context of integrated environmental and economic accounting, some Member States such as Austria, Denmark, Germany, Finland, Italy, Sweden and the United Kingdom have started to monitor the use of natural resources more comprehensively and to relate this to economic performance and industrial sectors (see Ministry of the Environment — Finland and Eurostat, 1999).

For measuring changes in consumption and production patterns, the UN presented a core set of indicators where the total material requirement (TMR) represented a major driving force (United Nations, 1998). In order to help operationalise the eco-efficiency concept, the EEA (1999b) proposed a set of EU environmental 'headline' indicators. Under the issue of 'Resource use' the 'ideal' environmental headline indicator of 'total material requirement (TMR)' was chosen.

2. Monitoring total material requirement

The TMR indicator comprises the cumulative volume of primary materials which are extracted from nature for the economic activities of a country. TMR indicates the material basis of an economy. It includes extraction from the domestic territory as well as the resource requirements associated with imports. TMR considers resource extractions for further processing (DMI = direct material input) as well as the hidden flows, that is, those extractions which are not used further but nevertheless burden the environment (overburden, extraction waste). The relation between foreign and domestic parts of TMR indicates possible shifts in environmental burden between countries.





Analogous to the cumulative energy requirements of nations, TMR accounts for global material requirements, including energy carriers and non-energy materials. TMR is a highly aggregated indicator, whereby all resource flows are aggregated in tonnes. TMR indicates a generic pressure to the environment, similar to energy requirements and overconsumption of water. The volume of resource extraction indicates in a general way the scale of local disturbances (by total extraction, including hidden flows), the throughput of the economy (DMI) and subsequent amounts of emissions and wastes.

Similar to aggregated energy indicators of energy requirements, TMR cannot be used to indicate specific environmental pressures. The different resource flows are associated with different specific impacts at various locations. Devastation of mining sites, disruption of natural habitats, contamination of groundwater and landscape changes may have an impact at the extraction site. Moreover, from a systems perspective it becomes clear that any input of material flows to the economy will lead to output flows sooner or later, many of them at other locations and in a changed composition. Thus, TMR indicates the total volume of throughput of the economy, that is, the potential amount of wastes and emissions. Some of these resource flows such as construction minerals are used for some decades; others, such as nutrition flows, may be released again to the environment within the same year. For example, around 80 % of the total material input (DMI

plus domestic hidden flows) into the German economy between 1991 and 1996 was released again to the environment within one year.

TMR comprises all resource extraction besides water and air. The data on domestic material requirement are provided by statistics on industrial production, agriculture, forestry and fisheries. These data are supplemented by specific information on the hidden flows, such as overburden and extraction waste in mining and quarrying, excavation by construction and dredging, and erosion of agricultural fields. The physical data on imports are provided by foreign trade statistics. Imports are grouped into raw materials, semi-manufactured products and final products. Based on statistics, raw materials are traced back to delivering countries. Specific extraction coefficients are used to account for the hidden flows of raw materials. The semi-manufactured products are classified according to the main constituent (e.g. steel, aluminium) and combined with data on cumulative material requirements. The final products are only accounted for by their own weight. Thus, the resulting values represent minimum estimates for the total material requirement. Although the presented values are preliminary, the order of magnitude seems to be valid enough for international comparisons.

TMR comprises all primary resources required for the production side of an economy, including trade and service activities. Each input contributing to value added is considered, in other words, pure transit is not accounted for. Countries with high dependence on either domestic resource extraction or imports exhibit high TMR values, irrespective of whether the resulting production is exported or consumed within the country itself. DMI comprises domestic resource production plus the physical amount of the imports.

The total material consumption (TMC) of resources of an economy can be derived from TMR by deducting the exports and their hidden flows. In contrast to TMR, TMC does not contain double counting of materials for individual economies.

So far, TMR has only been calculated for a few European countries such as Germany (Bringezu and Schütz, 1995, Bringezu, 1997), the Netherlands (Adriaanse et al., 1997, 1998), Finland (Juutinen and Mäenpää, 1999), and Poland (Mündl et al., 1999). The first calculation of TMR for the EU is presented and analysed below. At present, the United Kingdom is conducting research on the British TMR, and Denmark is considering a TMR study.

3. Data availability for the EU

The basic structure of TMR is reflected in its two main accounting components (see also the illustration in Chapter 2):

- domestic material flows (direct material inputs and hidden flows);
- foreign material flows (direct material inputs and hidden flows).

A detailed description of the step-by-step accounting of TMR for the EU is given in the technical annex to this report.

The study originally aimed at a timescale of 1985 to 1997. However, during that time the EU membership underwent significant changes. In 1986, Portugal and Spain joined the European Community. In 1990, the former GDR was reunited with the Federal Republic of Germany, thus increasing EU territory. The latest expansion of the European Union to EU-15 resulted from the accession of Austria, Finland and Sweden in 1995. The European Community has gradually been developing since its inception in 1952 (Table 1). Its monetary union is still incomplete in the year 2000. Twelve candidate countries are currently negotiating for accession.

Table 1: Member States of the European Union (as of March 2000)

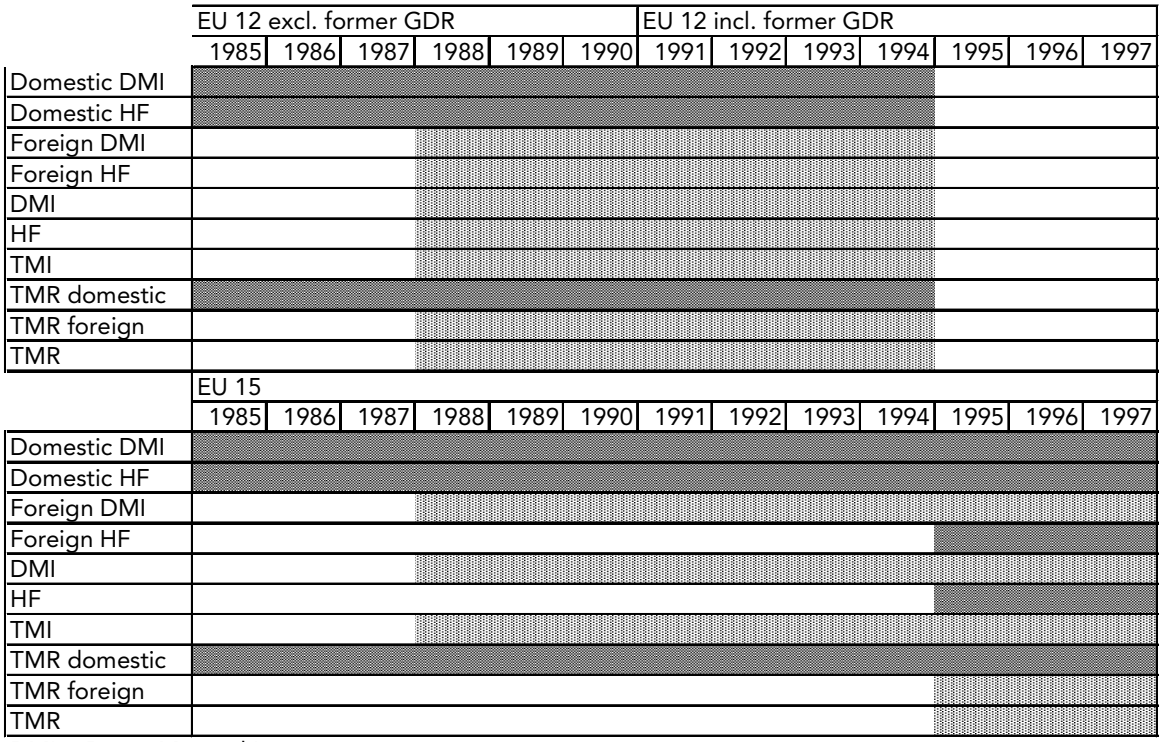
	Year of accession	Member of monetary union
Belgium	1952/58 ([1])	Yes
France	1952/58 ([1])	Yes
Germany	1952/58 ([1])	Yes
Italy	1952/58 ([1])	Yes
Luxembourg	1952/58 ([1])	Yes
Netherlands	1952/58 ([1])	Yes
Denmark	1973	([2])
Ireland	1973	Yes
United Kingdom	1973	
Greece	1981	([3])
Portugal	1986	Yes
Spain	1986	Yes
Austria	1995	Yes
Finland	1995	Yes
Sweden	1995	

([1]) 1952: European Community for Coal and Steel; 1958: European Economic Community.
([2]) Denmark will decide about application for membership by public vote in September 2000; Sweden and the United Kingdom are also considering public votes.
([3]) Greece has officially applied for membership (as of March 2000).
NB: The 12 candidate countries are: Estonia, Latvia, Lithuania, Poland, Czech Republic, Slovakia, Hungary, Slovenia, Romania, Bulgaria, Cyprus, Malta.

The gradual development of the European Union is associated with inconsistent statistics being available for TMR accounting. At the time of this study, a consistent timescale of TMR for EU-15 could only be established for 1995 to 1997 (Figure 1). For EU-12, a timescale was worked out from 1988 to 1994. It has to be noted, however, that this period of time was affected by German re-unification. Data for the former GDR have only been integrated into Eurostat's foreign trade statistics since 1991. Consequently, TMR of EU-12 from 1988 to 1990 is exclusive of the former GDR, but data from 1991 to 1994 include the 'five new federal states' of

the re-united Germany. The corresponding changes in population, GDP and GDP per capita are shown in Table 2.

Figure 1: Availability of data for TMR and its individual accounting aggregates in EU



DMI = Direct Material Input
HF = Hidden Flows
TMI = Total Material Input = Domestic TMR plus Foreign DMI
TMR = Total Material Requirement = DMI plus HF

Data for the domestic extraction of minerals were available for EU-15 from DG III's *European minerals yearbook* only until 1995. Therefore, TMR for EU-15 in 1996 and 1997 must be characterised as preliminary. However, for 1996 and 1997, data on domestic mineral extraction were available for Germany (database of Wuppertal Institute) and Finland (database of Thule Institute at University of Oulu, Finland, Juutinen and Mäenpää, 1999). Data for 1996 were also available for Austria (database of the Institute for Interdisciplinary Research and Continuing Education in Vienna — IFF). Data for the remaining years and other EU Member States were estimated by analysing the past trend of the single commodity inputs and continuing it for 1996 and 1997.

Table 2: Population, GDP and GDP per capita of EU-12 and EU-15 from 1988 to 1997

	Year	Population	GDP	GDP per capita	Population	GDP	GDP per capita
		1000	Billion ECU at 1985 prices	ECU per capita	Index 1988 = 100	Index 1988 = 100	Index 1988 = 100
EU-12 excluding former GDR	1988	323 425	3 700	11 440	100	100	100
	1989	324 747	3 827	11 785	100	103	103
	1990	326 646	3 940	12 062	101	106	105
EU-12 including former GDR	1991	344 251	4 221	12 262	106	114	107
	1992	345 832	4 270	12 347	107	115	108
	1993	347 391	4 267	12 284	107	115	107
	1994	348 593	4 249	12 189	108	115	107
EU-15	1995	371 588	4 826	12 988	115	130	114
	1996	372 850	4 909	13 167	115	133	115
	1997	373 890	5 041	13 482	116	136	118

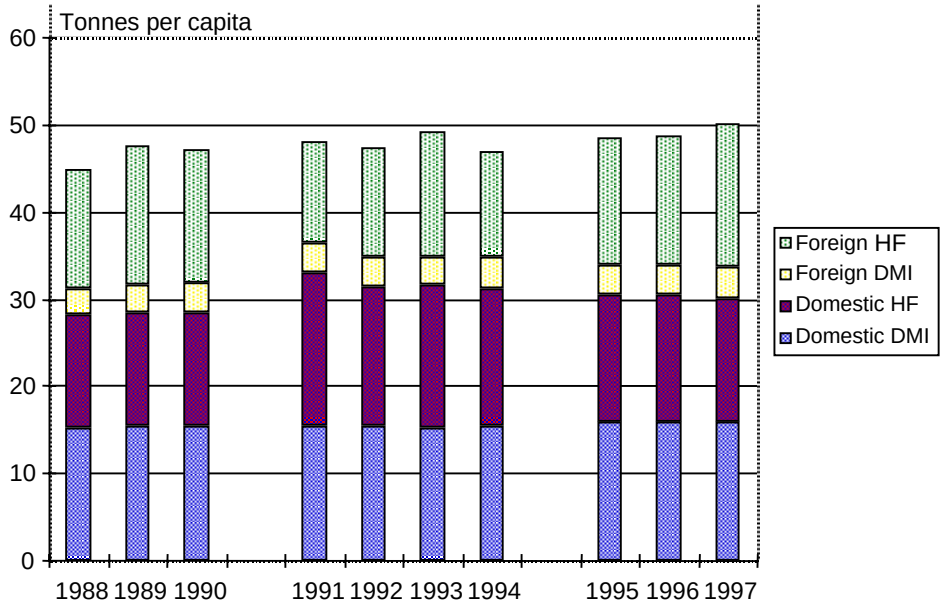
4. Total material requirement of the EU

TMR of EU-15 increased slightly from 1995 to 1997 from 18.1 to 18.7 billion tonnes, which is about 49 to 50 tonnes per capita. A similar per capita level of TMR ranging from 45 to 49 tonnes per capita had been observed for EU-12 between 1988 and 1994 (Figure 2). The aggregated material inputs of domestic DMI (15 to 16 tonnes per capita) and foreign DMI (3 to 4 tonnes per capita) were considerably similar throughout the study period, despite the changing economic territories.

The per capita domestic hidden flows showed greater variations (13 to 18 tonnes per capita) with its highest level in 1991 with the inclusion of the former GDR. This was mainly because of high quantities of lignite extraction as the major energy basis of the socialist economy of GDR, alongside huge amounts of overburden removed to extract the coal. After 1991, in the course of technological conversion to the West German market economy, lignite mining in the former GDR, now the 'neue *Länder*' within the re-united Germany, was drastically reduced leading to a significant decrease in domestic TMR per capita in the EU. For example, the total German contribution by lignite overburden to domestic hidden flows of the EU decreased from 7.3 tonnes per capita in 1991 to 4.4 tonnes per capita in 1997.

Hidden flows associated with imports varied between 12 and 16 tonnes per capita in EU-12 from 1988 to 1995 with a peak in 1989. These variations were strongly determined by imports of precious metals as raw materials. Foreign hidden flows of EU-15 increased from 14.7 to 16.5 tonnes per capita from 1995 to 1997, also mainly because of imported metals.

Figure 2: TMR of EU in tonnes per capita, 1988 to 1997



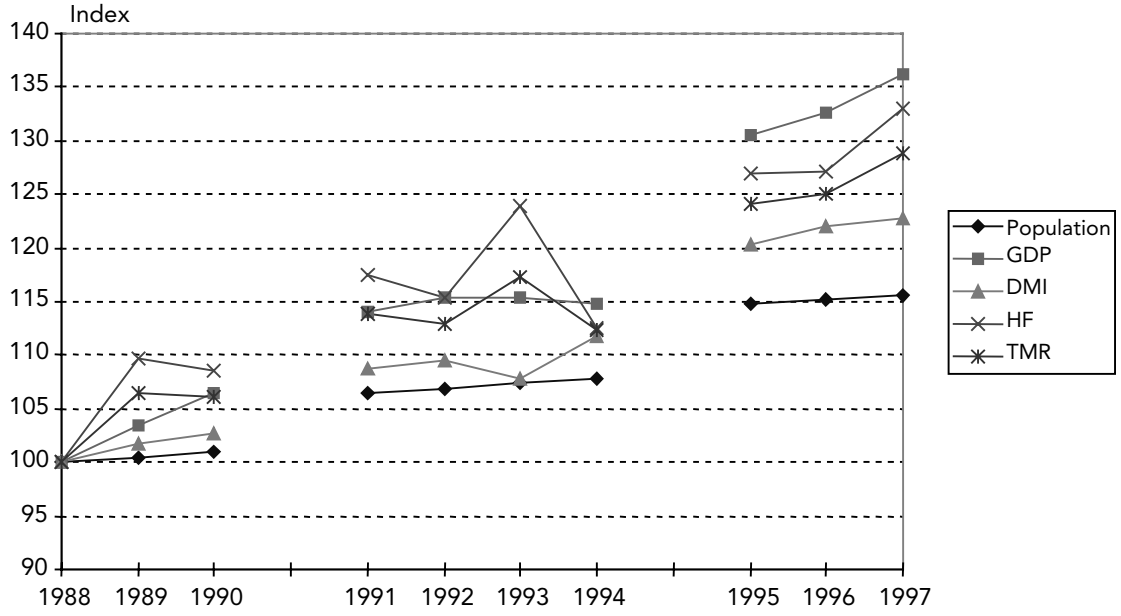
DMI = direct materials input; HF = hidden flows
NB: 1988 to 1990 refers to EU-12 excluding the former GDR; 1991 to 1994 refers to EU-12 including the former GDR; 1995 to 1997 refers to EU-15.

In comparison with socioeconomic data for population and GDP (see also Table 2), the relative developments of DMI, hidden flows and TMR are shown in Figure 3. The expansion of EU from 1990 to 1991 and from 1994 to 1995 was associated with a higher increase in GDP than in population size. From 1988 to 1997 resource flows of the EU increased to a higher degree than population numbers but to a lower degree than GDP. Direct material inputs increased about 6 % after inclusion of the former GDR in 1991 but did not change significantly until 1993. DMI increased by about 8 % in EU-15 in 1995 compared to EU-12. DMI in EU-15 increased slightly from 1995 until 1997.

Most obvious changes with material flows occurred with hidden flows. These were about 8 % higher in 1991 compared to 1990 (mainly because of overburden by lignite mining in the former GDR, see before), increased until 1993 and decreased again in 1994. In EU-15, from 1995 to 1997, the absolute level of hidden flows was only slightly higher than in EU-12 in 1993. Due to increased levels of both DMI and hidden flows, the TMR in EU-15 in 1995 was about 12 % higher than in EU-12 in 1994. TMR increased from 1995 to 1997 in EU-15 by about 4 %.

These basic data show that with expanding economic territories of the EU material resource requirements increased, though with different levels for DMI, hidden flows and TMR indicating significant changes in hidden flow ratios to direct material inputs. This will be addressed in the following chapters. The temporal trends of the material productivities per unit of gross domestic product will be described later (see Chapter 8).

Figure 3: Population, GDP, DMI, hidden flows and TMR of EU, 1988 to 1997



GDP = gross domestic product (given at constant prices for 1985); DMI = direct materials input (tonnes); HF = hidden flows (tonnes); TMR = total material requirement (tonnes).
NB: 1988 to 1990 refers to EU-12 excluding the former GDR; 1991 to 1994 refers to EU-12 including the former GDR; 1995 to 1997 refers to EU-15.

4.1. A closer look at the major flows

To find out its main components, TMR was differentiated by major material flows which are fossil fuels, minerals, metals, biomass excavation and erosion.

Fossil fuels

More than two thirds (72 %) of EU-15 TMR in 1995 are represented by resource flows of fossil fuels, metals and minerals (Figure 5). On the per capita average, EU-15 in 1995 extracted 14.2 tonnes of fossil fuel resources. Energy carrier plus hidden flows amounted to 29 % of TMR. Due to a lower use of energy and a reduced amount of coal use in Europe, this is only 43.4 % of the 1994 fossil fuel resource requirement of the United States. Nevertheless, in some Member States such as Germany which still depend to a large extent on coal extraction, the fossil fuels reach the same order of magnitude as in the United States. From the countries studied, Finland succeeds with the lowest fossil fuel resource requirement.

Minerals

Mineral resources are mainly used for construction. Production in EU-15 demands 10.7 tonnes per capita (t/cap.) The requirements are almost the same in EU-15 and in the United States. From the Member States studied, Germany and Finland had the highest rate of mineral extraction due to the production of sand and gravel as well as natural stones in Germany, and the extraction of gravel in Finland. The German values are twice those of EU-15 as a whole, due to construction activities for houses and infrastructures which still rely on high inputs of minerals for concrete. The lowest requirements for minerals are shown for the Netherlands.

Metals

Resource requirements for metals are at a higher level in EU-15 (10.1 t/cap.) than in the United States (9.4 t/cap.). A significantly higher level is reached in Finland (21.5 t/cap.) where metal manufacturing still represents a significant element in industrial production. In comparison, the metal resource requirements of Japan in 1994 were 1.6 times lower than those of EU-15 in 1995.

Biomass

With 6 t/cap., biomass represents 12 % of TMR in EU-15. This is only 2 % lower than the US biomass harvest in 1994. Most of the biomass stems from agriculture. However, Finland provides a twofold exception. Firstly, the input of biomass amounts to 23 % of TMR, and secondly, the biomass is dominated by forestry cuts which also represent a significant basis for the Finnish export industry. Compared to EU-15 as a whole, the proportion of regrowing resources in Finland is 1.9 times higher.

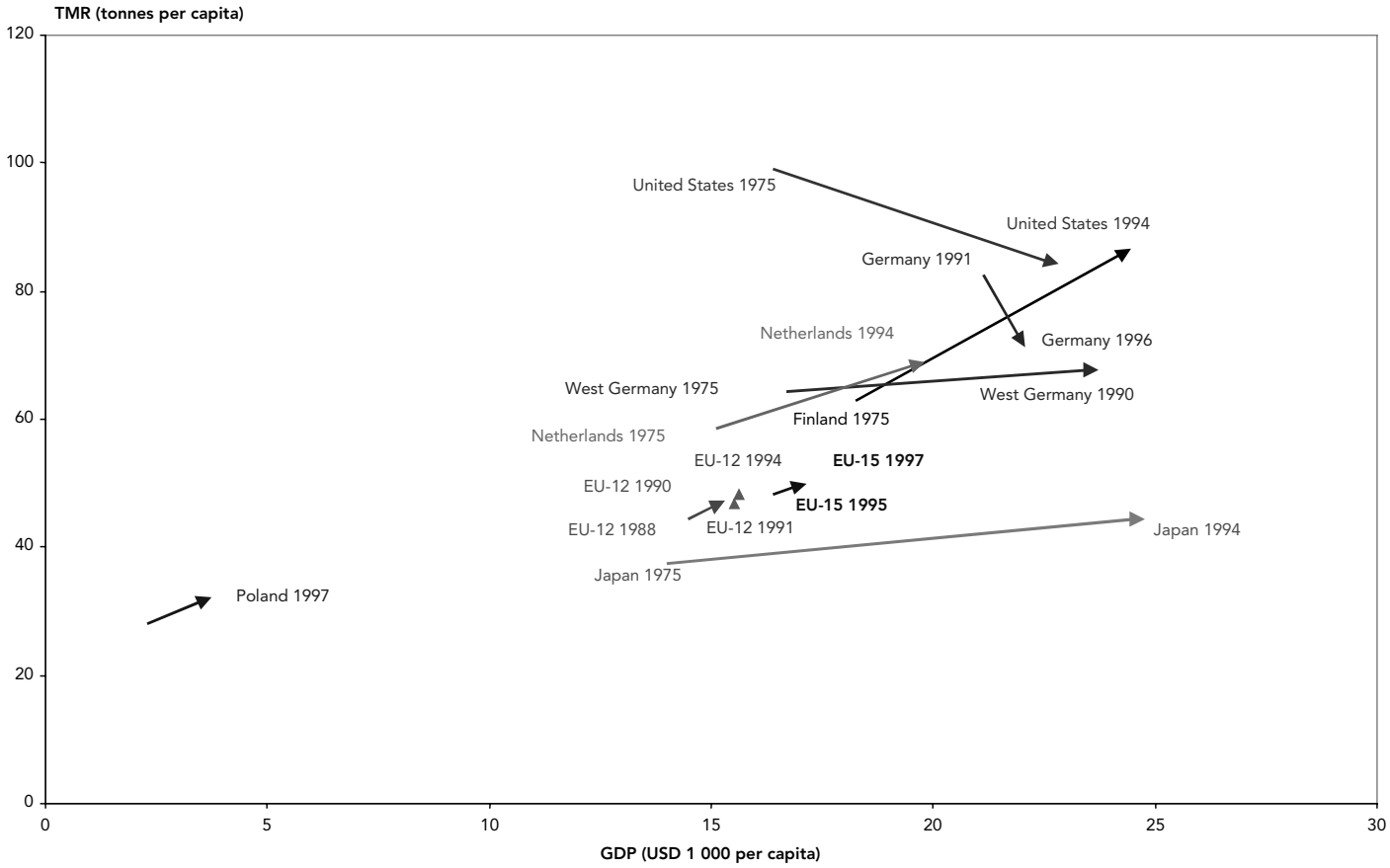
Erosion

Erosion of agricultural fields contributes to only 10 % of TMR in EU-15. In the United States this problem has been reduced by significant policy programmes but still exceeds the EU-15 level by 2.9 times. From the Member States studied, only the Netherlands is clearly above the average. This reflects the high amount of agricultural imports mainly from non-European countries. Products such as coffee and cocoa which are traded and processed in the Netherlands are associated with high levels of erosion in countries of the south.

4.2. Comparing TMR in the EU with Japan and the United States

In 1995, TMR of EU-15 amounted to 18.1 billion tonnes, which is 49 tonnes per capita. This was significantly lower than TMR of United States, which was 84 t/cap. in 1994. And it was not much higher than the value for Japan in 1994 with 45 t/cap. Both countries have a higher GDP per capita than EU-15. In comparison, in Poland in 1995 GDP per capita was only 19 % of EU-15 whereas TMR has already reached 59 % of the Member States as a whole (Figure 4).

Figure 4: TMR and GDP of the EU in comparison to some Member States and other countries

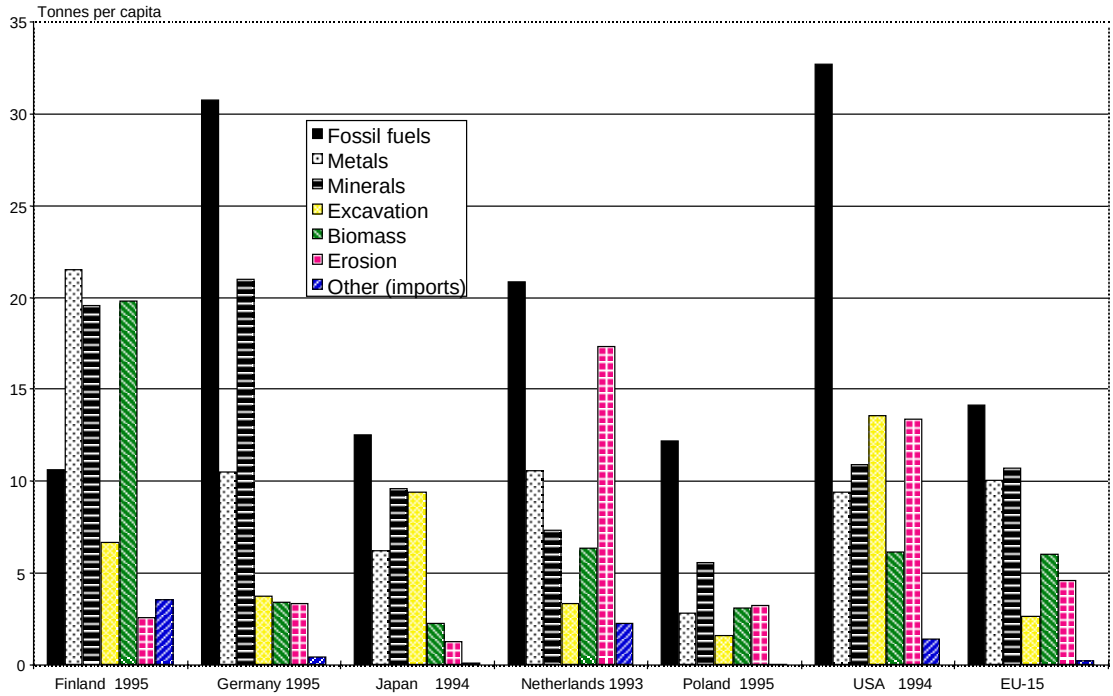


Note: GDP given at constant prices and exchange rates for 1990.
Source: Wuppertal Institute, WRI, NIES, VROM, Thule Institute, INE and Warsaw University.

With respect to future development, the question arises as to whether EU-15 may successfully decouple further economic growth and TMR, and whether it may improve resource productivity even further than countries like Japan. This country had material productivity in 1994 which was 1.5 times higher than EU-15 in 1995. One may expect that material productivity of a country like Poland would have to rise 3.1 times as much if it is to even come near the current EU-15 average. Nevertheless, within EU-15 there is a significant range of material productivity. Finland, the Netherlands and Germany are all below the average level (62 %, 80 %, and 87 % respectively). Further work is needed to indicate those Member States which perform significantly higher material productivity in terms of GDP per TMR.

😐 From 1988 to 1997, the level of TMR per capita in the EU remained constantly high, indicating continuous pressure on the global environment due to resource extraction for the EU economy. Between 1995 and 1997, TMR per capita increased by 3 %. This contributed to an increase, from 1988 to 1997, by 11 %. With 49 t/cap., TMR of EU-15 as a whole is much less than TMR of the United States and similar to the level of Japan. TMR of EU-15 is dominated by energy, metals and mineral resources.

Figure 5: Composition of TMR in EU-15, selected Member States and other countries



NB: Hidden flows are included in fossil fuels, metals and minerals or are represented by excavation and erosion.

Source: Wuppertal Institute, WRI, NIES, VROM, Thule Institute, INE and Warsaw University.

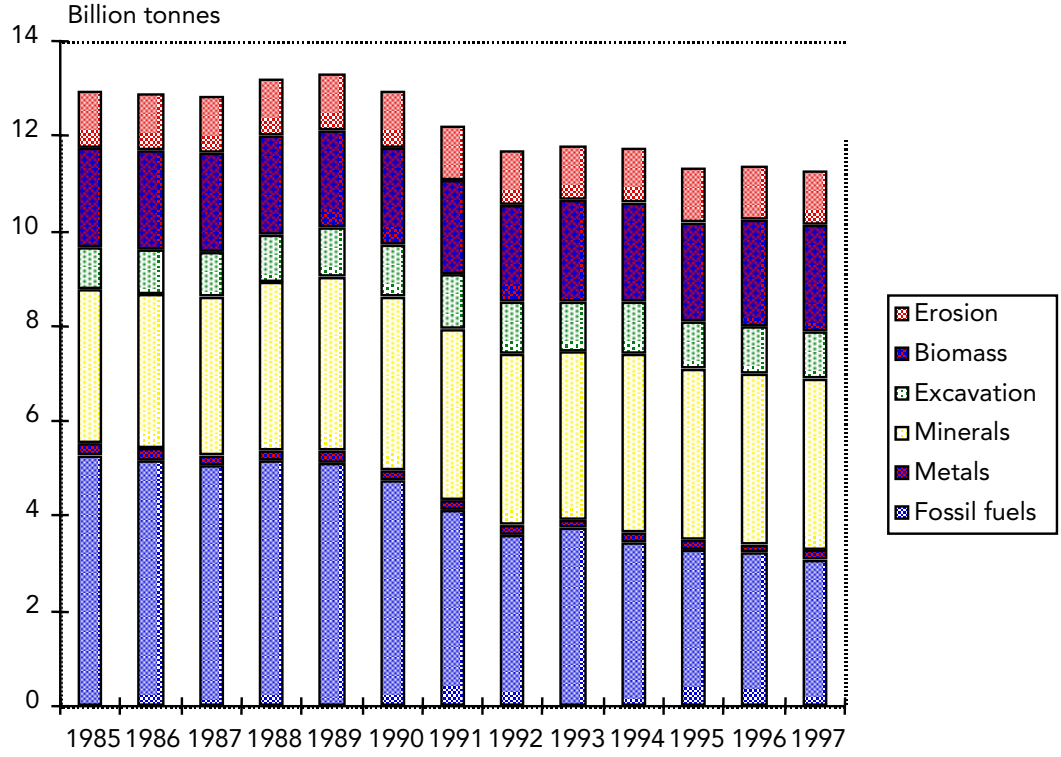
5. Domestic resource extraction

In 1997, domestic resource extraction within EU-15 amounted to 30 t/cap. which represents 60 % of TMR. This 'domestic TMR' had declined from 12.9 billion tonnes in 1985 to 11.3 billion tonnes in 1997. This resulted mainly from a decline in the extraction of fossil fuel resources (Figure 6). In 1985, energy carrier production contributed 41 % to domestic TMR, whereas in 1997 the amount was reduced to 28 %.

The reduction resulted mainly from a decline in lignite production and was a consequence of German re-unification (Figure 7). The energy supply of the former GDR had been heavily dependent on domestic lignite extraction. After 1990, a significant amount of the old fashioned production facilities in the eastern part of Germany were closed. The German production of lignite went down from 433 million tonnes in 1985 to 177 million tonnes in 1997, and its contribution to EU-15 production volume was reduced from 87 to 72 %. In Germany lignite production gave rise to political debate and was highly controversial due to continuous planning which led to the resettlements of entire villages located above the deposits.

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

Figure 6: Domestic resource extraction in EU-15 between 1985 and 1997



NB: Before 1990, the values represent the combined extraction of the former West Germany and East Germany.

Not as fast, but still significant compared to lignite, the extraction of hard coal resources declined from 216 million tonnes in 1985 to 117 million tonnes in 1997. The main producers in 1997 were the United Kingdom, Germany and Spain with 40.1 %, 39.6 % and 15.4 % of sold hard coal, respectively. However, in terms of total extraction (including hidden flows) these countries generated 23.2 %, 31.4 % and 42.8 %, respectively. Thus, Spain produces hard coal with much higher hidden flows than the other countries.

Interestingly, the decline in energy resource extraction was highest for those energy carriers with the highest proportion of unused extraction (that is the so-called hidden flows) (Figure 7, lower part). For lignite, on average 9 tonnes of overburden have to be removed in order to extract 1 tonne of the energy carrier. This ratio, which indicates the poor resource efficiency of primary production, has grown gradually. For hard coal the ratio is much lower but is also slowly increasing. The ratios for the other energy carriers are significantly lower. Thus, as regards the extraction of energy resources, highly resource intensive coal production is being substituted by the increased use of less resource intensive gas.

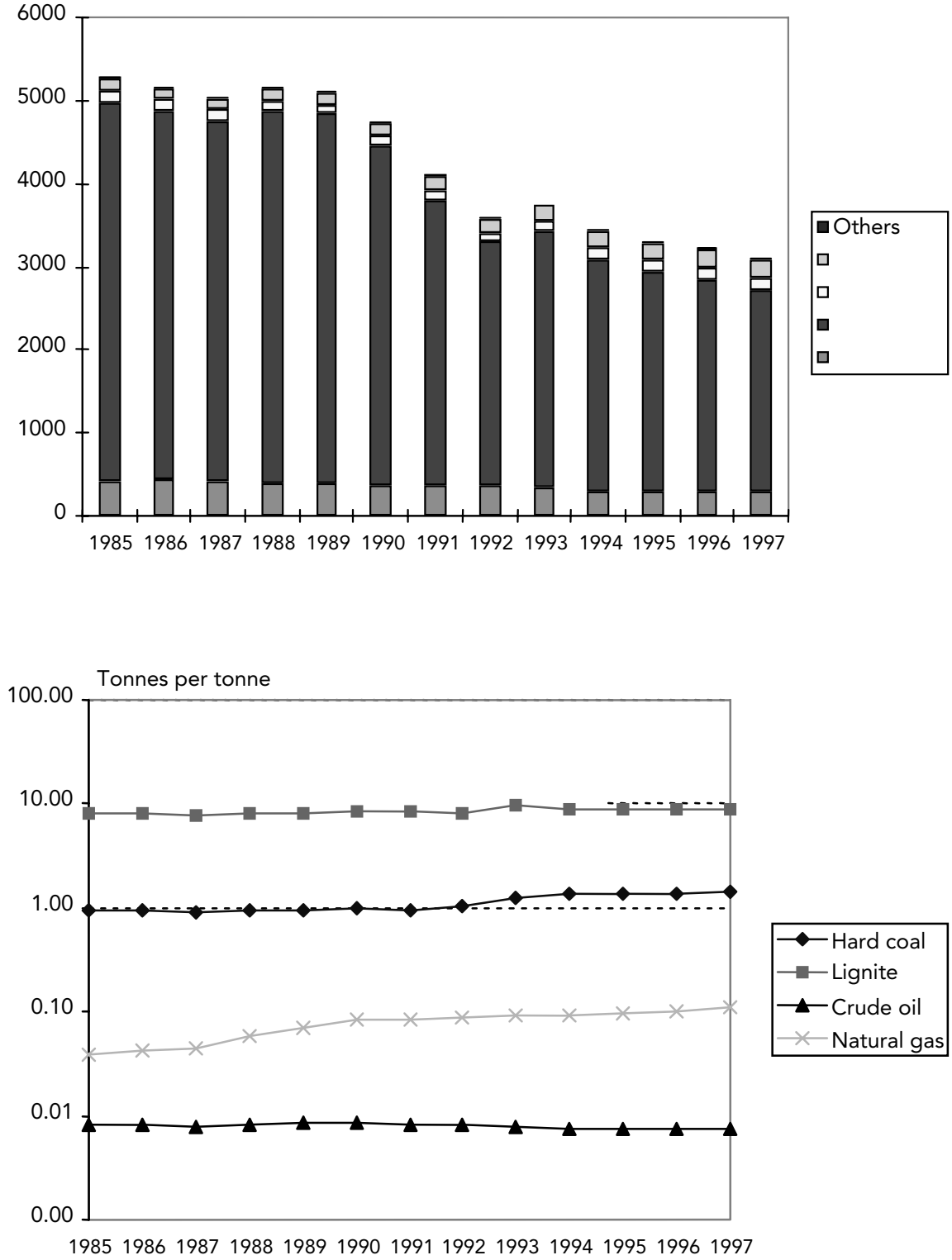
The extraction of minerals has risen from 25 % in 1985 to 32 %, i.e. the highest proportion of domestic TMR in 1997. The absolute extraction volume has increased from 3.2 billion tonnes to 3.6 billion tonnes (Figure 8), although the composition of the mineral requirements has remained rather constant. Sand and gravel, crushed rock, limestone and dolomite, other natural stones and clay together represent 97.7 % of the mineral resource extraction. For mineral resources the proportion of hidden flows is relatively low with 18.3 % altogether.

The importance of mineral requirements in terms of domestic resource extraction has increased significantly. In recent years the volume ranks first and exceeds domestic energy resource extraction. Thus, quarrying activities altogether should be taken as seriously as mining activities. The associated pressure on the environment — hydrological changes, habitat disturbances, growth of built-up areas, potential construction waste — which is associated with the overall extraction volume has gradually increased.

☺	Domestic resource extraction within the EU-15 countries decreased from 1985 to 1997 by 13 %. The reduction was mainly due to a decline in lignite production in the eastern part of Germany after re-unification. Nevertheless, domestic extraction tends to diminish resource intensive primary production. Mineral resource extraction increased towards the dominant part of domestic TMR.

Figure 7: Domestic extraction of fossil energy resources in EU-15 between 1985 and 1997

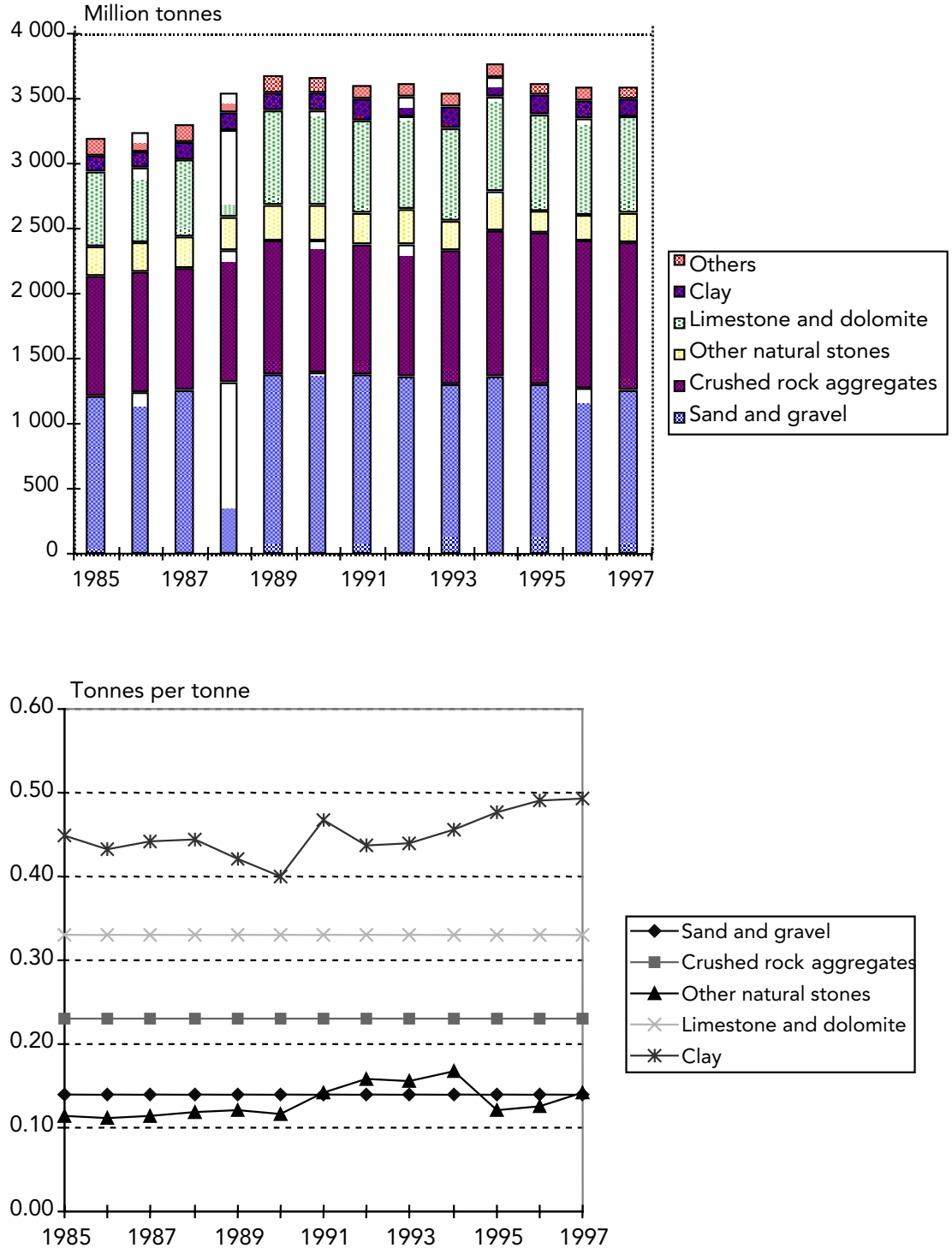
Upper chart: absolute (including hidden flows)
Lower chart: ratios of unused to used extraction



NB: Before 1990, the values represent the combined extraction of the former West Germany and East Germany.

Figure 8: Domestic extraction of mineral resources in EU-15 between 1985 and 1997.

Upper chart: absolute (including hidden flows)
Lower chart: ratios of unused to used extraction



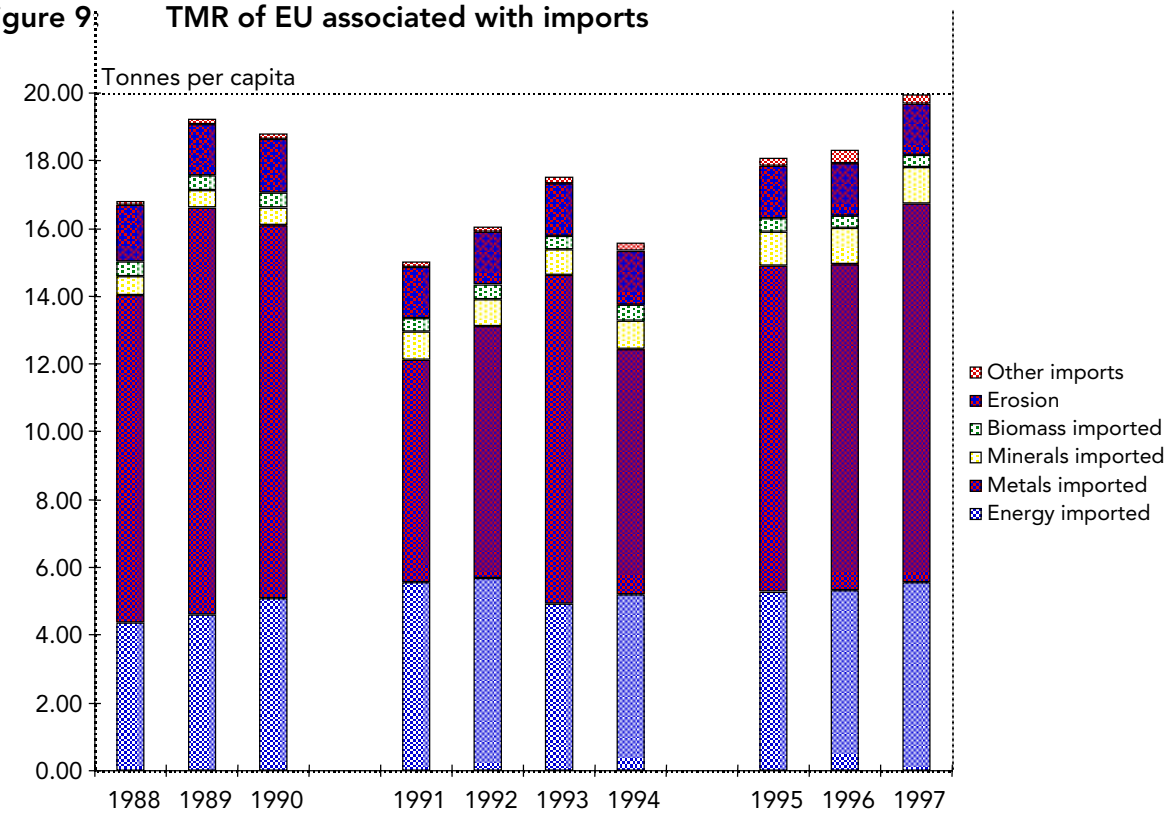
NB: Before 1990, the values represent the combined extraction of the former West Germany and East Germany.

6. Resource requirements of the EU in foreign countries

In 1997, the up-stream resource extraction associated with imports of EU-15 was at least 20 t/cap. (Figure 9), thus contributing 40 % to TMR. The major components are metal and energy resources with 55.9 %, and 27.8 % respectively. Biomass imports amount to only 1.9 %, although they are linked to erosion with 7.6 % of foreign TMR. The regrowing proportion of foreign TMR is 1.9 %, compared to 18.3 % of domestic TMR. Thus foreign TMR contributes especially to the depletion of naturally non-renewable resources.

Foreign TMR per capita in EU-12 and EU-15 between 1988 and 1997 varied from about 15 to 20 tonnes per capita. The variations were mainly caused by imported metals (Figure 9), especially by resource requirements for precious metals.

Figure 9: TMR of EU associated with imports



NB: Foreign resource extraction as a basis for do mestic activities. 1988 to 1990 refers to EU-12 excluding the former GDR; 1991 to 1994 refers toEU-12 including the former GDR; 1995 to 1997 refers to EU-15.

Recent developments since 1995 exhibit a slightly increasing tendency of foreign TMR by 10 % to 20 t/cap. The increase is mainly due to an expansion of the import of precious metal ores.

From 1995 to 1997 the import of precious metal ores grew by 51 %. As a result of the scarcity of precious metals, the extraction waste of mining is extraordinarily high. In general, the world average hidden flow factor of gold mining has been applied to account for the resource requirements of that group (comprising gold, platinum, rhodium, palladium, iridium, osmium and ruthenium). The value of

259 010 tonnes per tonne also represents a minimum estimate for other precious metals such as platinum. In 1997, resource flows of precious metals contributed the highest amount (75.2 %) to metal resource extraction for imports to EU-15 (it was 63.8 % in 1995 and 72.5 % in 1996, between 53 % and 69 % from 1988 to 1990, and between 14 % and 75 % from 1991 to 1994). In comparison, resource extraction for iron and copper ore imports in 1997 ranked second and third with 15.7 % and 3.4 %, respectively. The calculated order of magnitude of 1 to 1.8 billion tonnes of resource flows for precious metal imports of a volume of 3 700 to 5 600 tonnes between 1995 to 1997 provides ample evidence that more information is needed on the specific material flows and the environmental impacts of precious metal mining induced by manufacturing and investments in EU-15 (virtually the entire silver demand is for fabrication; most of the platinum demand is for manufacturing sectors, for use especially in catalytic converters; usually most of the global gold production is required by manufacturing sectors, predominantly by the jewellery industry, but high quantities are also demanded for governmental and private hoarding which varies strongly from year to year).

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

Compared to domestic resource extraction, there is a remarkable difference in the hidden flow to commodity ratio.

Table 3: Ratios of hidden flows to commodities for EU-15 in 1995

	Domestic	Foreign	Total
Fossil fuels	3.44	1.63	2.53
Metals	0.94	16.08	11.33
Minerals	0.22	4.41	0.32
Agricultural biomass	0.62	5.90	0.88
Total	0.92	4.28	1.52

The import of fossil fuels (not electricity) has a significantly lower hidden flow ratio than domestic extraction of energy resources. This is due to the fact that the imports are mainly oil and natural gas and those materials are associated with lower hidden flows than lignite and hard coal which some of the Member States still rely on. Any measure which effectively reduces the energy consumption of industry, transport and households will contribute to less environmental burden of resource extraction, either domestically or in foreign countries.

The import of metal resources is associated with 17 times higher hidden flows than domestic extraction. Ore mining within EU-15 plays only a minor role and obviously concentrates on deposits with relatively high efficiency of extraction and lower volume burden to the environment. However, most of the base metals such as iron, aluminium and copper are imported. Precious metals with the highest environmental burden by mining are mostly sourced from outside. Thus, recycling

strategies should be fostered to raise resource productivity of base metal production. The consumption of luxury goods and patterns of financial investments gain increased importance as driving forces of relevant resource flows of EU-15.

The dominant contribution to mineral requirements comes with the import of diamonds. The small amount of 37 000 to 44 000 kg has been linked to the calculated extraction of 195 to 232 million t. This represents 68.1 % of the mineral resource share of foreign TMR in 1997. The additional import of 2 337 to 2 450 tonnes of other precious stones has not yet been attributed to a certain amount of hidden flows due to insufficient data availability. However, in some cases precious stone mining may reach the hidden flow ratio of gold. The potential extent of these resource flows clearly indicates the need for further information.

The import of agricultural products to EU-15 is associated with a higher amount of erosion than domestic agriculture. This results from the import of products such as coffee and cocoa which are cultivated in tropical countries. Erosion is influenced by many parameters, e.g. rainfall, slope, cultivation practices. Worldwide erosion is still a severe threat to soil availability and fertility. Popularity of labelled products shows that European producers and consumers are willing to use their influence to support sustainable agricultural practices for food and feedstuff consumed from foreign countries.

Altogether, a considerable amount of the resource flows for EU imports (33 to 38 % for EU-15 from 1995 to 1997; between 21 and 45 % for EU-12 from 1988 to 1994) is associated with luxury commodities. This is corroborated by the fact that imports of finished products such as jewellery, gold and silver goods, and plated ware contribute to further resource requirements. These have not yet been included in the presented foreign TMR data, although estimations indicate that they may contribute an additional amount of 1 t/cap.

☹	Requirements for foreign resources underwent a significant variation due to fluctuating imports of metals. Although the extent on a per capita basis was similar for EU-12 (1988 to 1994) and EU-15 (1995 to 1997), there was an increase of 23 % from 1988 to 1997. The expansion of EU-12 to EU-15 led to an increased dependency on foreign resource extraction. From 1995 to 1997, EU-15 requirements for foreign resources increased by 11 %. Future analyses will have to prove whether this resulted from metal market variations or reflected a continuous trend. Imported metals, minerals and agricultural products are associated with higher hidden flows per commodity than domestic products, indicating a relatively higher burden to the environment of foreign countries. Foreign TMR is significantly influenced by EU-15 demand for luxury and precious commodities.

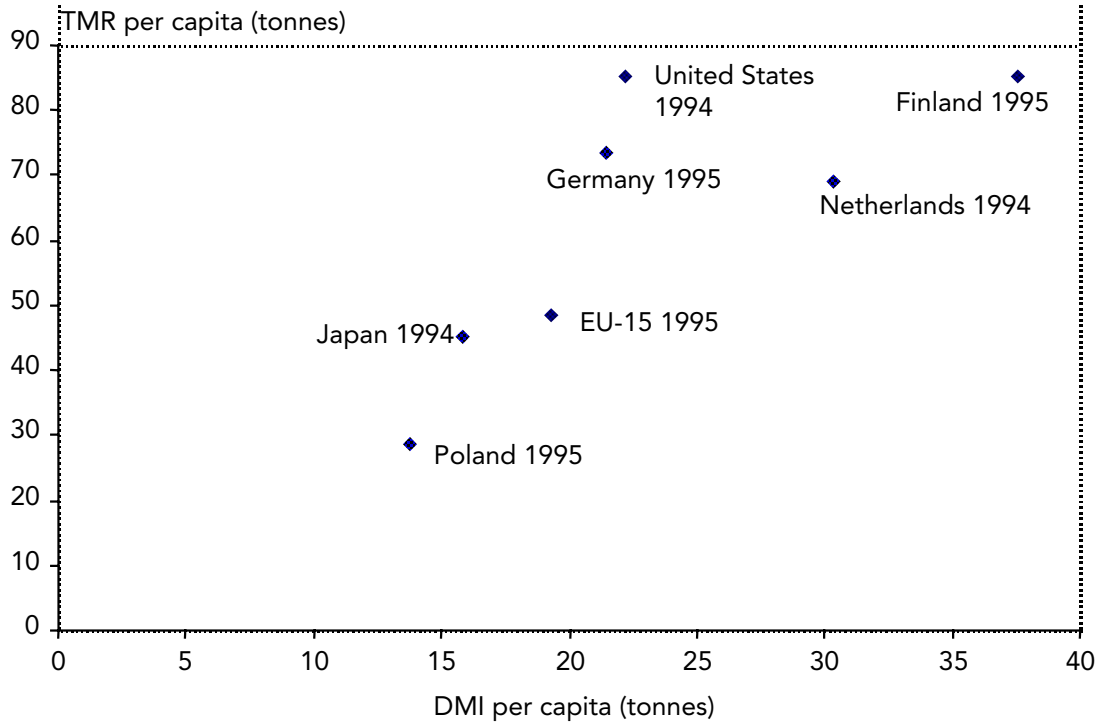
7. Direct material inputs

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

Based on the background that DMI comprises only the part of TMR which is used for further processing, the question arises as to whether it may be sufficient to indicate progress towards resource productivity. Taking EU-15 as a whole and comparing this economic region with countries for which TMR as well as DMI have been calculated, there is an indication that a high DMI goes in line with a high TMR and vice versa (Figure 10). If such a correlation could be proved for the Member States, national and European statistics may use DMI to monitor materials productivity regularly. Domestic TMR have to be accounted for if the burden of resource extraction to the country's own environment is to be monitored. In addition, foreign TMR can be used to indicate the burden sharing and problem shifting between countries and regions.

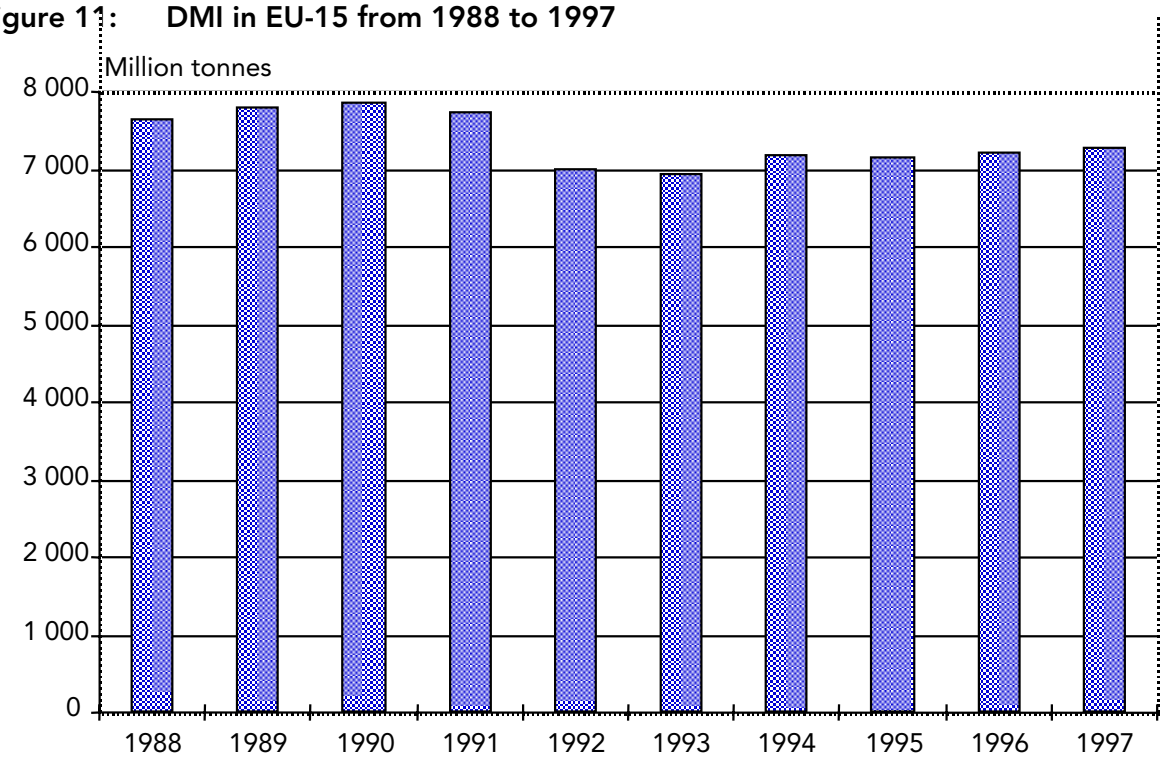
The DMI of EU-15 exhibited a moderate reduction in absolute terms by 5 % between 1988 and 1997 (Figure 11). This was equal to an 8 % decline per capita from 21.2 tonnes to 19.5 t. Most of the change occurred at the beginning of the nineties and was mainly a result of a decline of the imports by 1 t/cap. However, since 1993, DMI of EU-15 has followed a slightly increasing trend. Thus, in terms of DMI there is no indication of absolute dematerialisation.

Figure 10: TMR per capita in relation to DMI per capita



Source: Wuppertal Institute, WRI, NIES, VROM, Thule Institute, INE and Warsaw University.

Figure 11: DMI in EU-15 from 1988 to 1997



NB: Before 1990, the values represent the combined extraction of the former West Germany and East Germany.
Source: Wuppertal Institute.

In 1997, Finland used the highest amount of DMI with 39 t/cap., almost two times more than EU-15 as a whole, whereas for Portugal and Italy the lowest values are recorded with 15 t/cap., i.e. 75 % of EU-15 (Table 4). From 1988 to 1997, slightly declining trends of DMI per capita (around 1 to 3 % less than in 1988) could be observed for Finland, Sweden, Germany, France and Italy. A significant increase, however, took place in Portugal (+ 36 %), Belgium and Luxembourg (+ 24 %), Greece (+ 19 %), Denmark (+ 17 %) and Spain (+ 12 %).

Table 4: DMI and related materials productivity of GDP in Member States 1988–97

(NB: The changes recorded in Table 2 for Member States do not add to the EU-15 value because Member States include intra EU-15 trade whereas DMI of EU-15 does not).

Direct material input (DMI)

	t per capita 1997	ECU per kg 1997	Change 1988 to 1997 (%)	
			t per capita	ECU per kg
Finland	39	0.45	– 3	11
Ireland	35	0.41	3	77
Sweden	34	0.52	– 3	7
Belgium and Luxembourg	34	0.41	24	– 5
Denmark	33	0.56	17	– 2
Netherlands	29	0.51	4	17
Austria	24	0.59	2	14
Germany	24	0.70	– 2	33
Spain	22	0.35	12	6
France	22	0.70	– 1	13
Greece	20	0.31	19	– 6
EU-15	20	0.69	– 8	28
United Kingdom	19	0.71	0	12
Portugal	15	0.30	36	– 5
Italy	15	0.81	– 3	17

NB: Before 1990, the values represent the combined extraction of the former West Germany and East Germany.
Source: Wuppertal Institute.

😐 Direct input of primary materials (DMI) per capita of EU-15 declined by 8 % at the beginning of the nineties but increased slightly afterwards. The order of magnitude seems to remain constantly high.

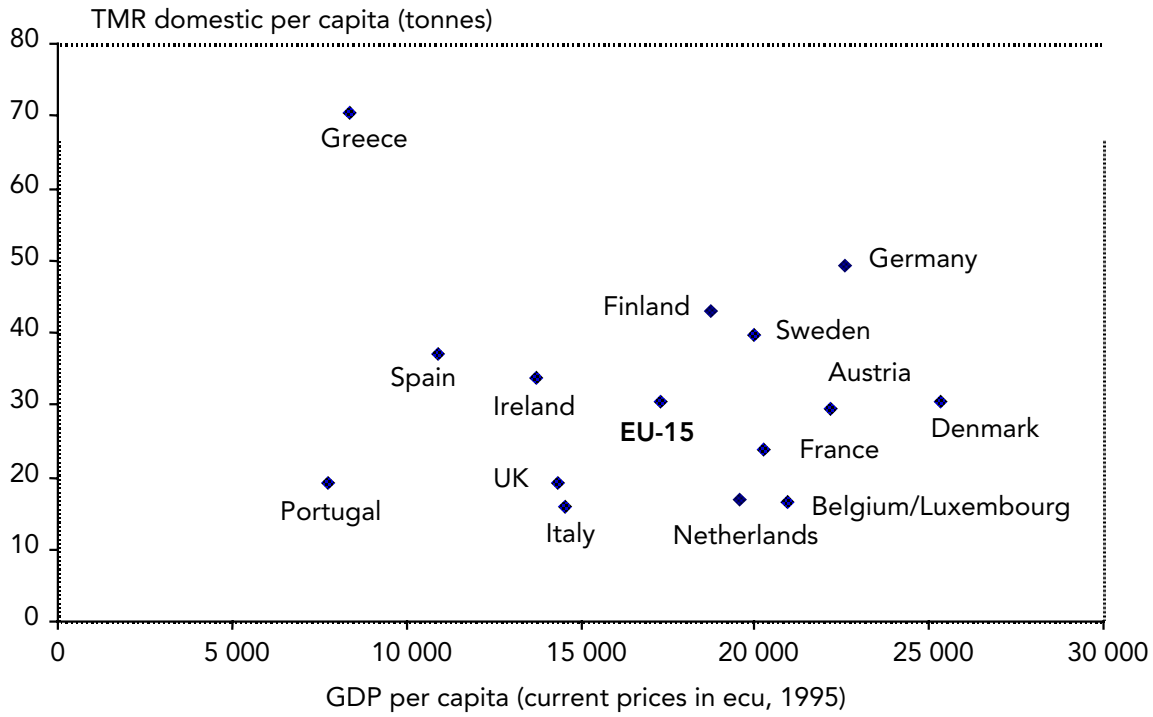
8. Material productivity

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

There is no correlation between domestic resource extraction and GDP (Figure 12). Thus, GDP of the Member States is rather independent of domestic TMR. In other words, a high economic performance can be reached with low rates of resource extraction from a country's own territory. In 1995, Denmark had the highest GDP per capita within EU-15 while domestic TMR was within the lower third of the range. Greece on the other hand had the highest rate of domestic TMR with 71 t/cap. and lowest GDP. This resulted from the high volume of domestic lignite production in Greece. As a consequence domestic resource productivity of ECU 84 per tonne exhibited the lowest value within EU-15. The highest domestic resource productivity was recorded for the Netherlands with ECU 847 per tonne.

Naturally, smaller countries such as Belgium and Luxembourg with a high GDP may import more materials to compensate for the lack of own primary production. The pure national or intraregional analysis must be supplemented by considering the imports.

Figure 12: Domestic TMR and GDP of EU-15 and Member States in 1995



NB: GDP in ecu, current prices, 1995.
Source: Wuppertal Institute.

Considering EU-15 as a whole more economic wealth could be provided from less use of materials in 1997 compared to 1988. The relation of GDP to DMI increased

altogether by 28 %. Although since 1992 DMI has remained rather constant, relative decoupling can be monitored based on significant economic growth.

Within the Member States the most significant decoupling took place in Ireland and Germany with increases of direct materials productivity by 77 % and 33 %, respectively (Table 4). In contrast, this productivity declined in Belgium and Luxembourg, Denmark, Greece and Portugal where DMI increased without gain in GDP.

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

When comparing DMI and GDP for EU Member States between 1988 and 1997 (Figure 13), three groups of Member States can be distinguished:

Group A: Finland, France, Italy, Sweden and the United Kingdom managed to combine economic growth with reduced DMI. With a reduced extraction of building minerals these five Member States showed that absolute dematerialisation is possible.

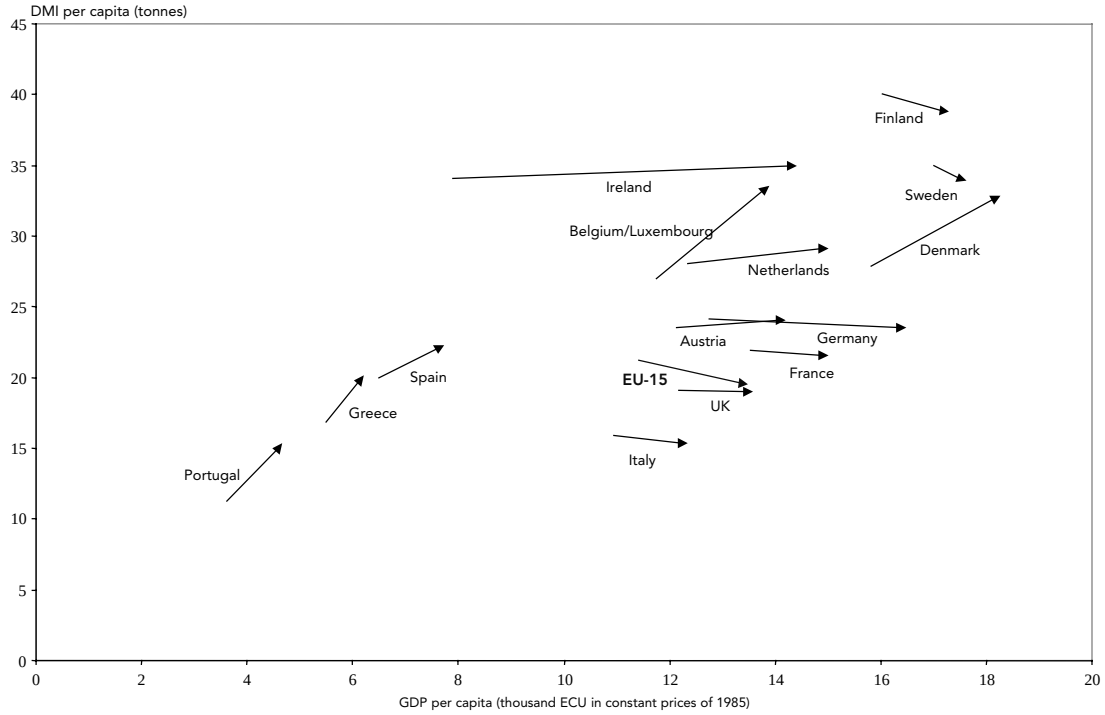
Group B: Germany and Ireland achieved significantly higher GDP with a rather constant DMI. In these two Member States, a relative decoupling of direct material requirements and economic growth has occurred.

Group C: A higher economic performance is associated with higher DMI in Austria, Belgium and Luxembourg, Denmark, Greece, the Netherlands, Spain and Portugal.

The EU as a whole performed best with a reduction of DMI/capita by 8 % while GDP/capita increased by 18 %. Altogether direct material productivity grew by 28 % in the EU between 1988 and 1997. It should be noted that the values of the Member States do not add up to the EU value because Member States' DMI include intra-EU trade whereas DMI of EU do not. Due to the rather constant level of DMI since1992, the EU as a whole can be grouped with Germany and Ireland (Group B) — challenging it to follow the countries in Group A by using less material resources while achieving a higher economic performance.

☺	Direct resource productivity of EU-15 increased by 28 % from 1988 to 1997. Whereas in most Member States economic growth had been associated with increased DMI, reduced dependence on direct material inputs could be recorded for Finland, France, Italy, Sweden and the United Kingdom.

Figure 13: GDP and DMI per capita in EU-15 and the Member States between 1988 and 1997



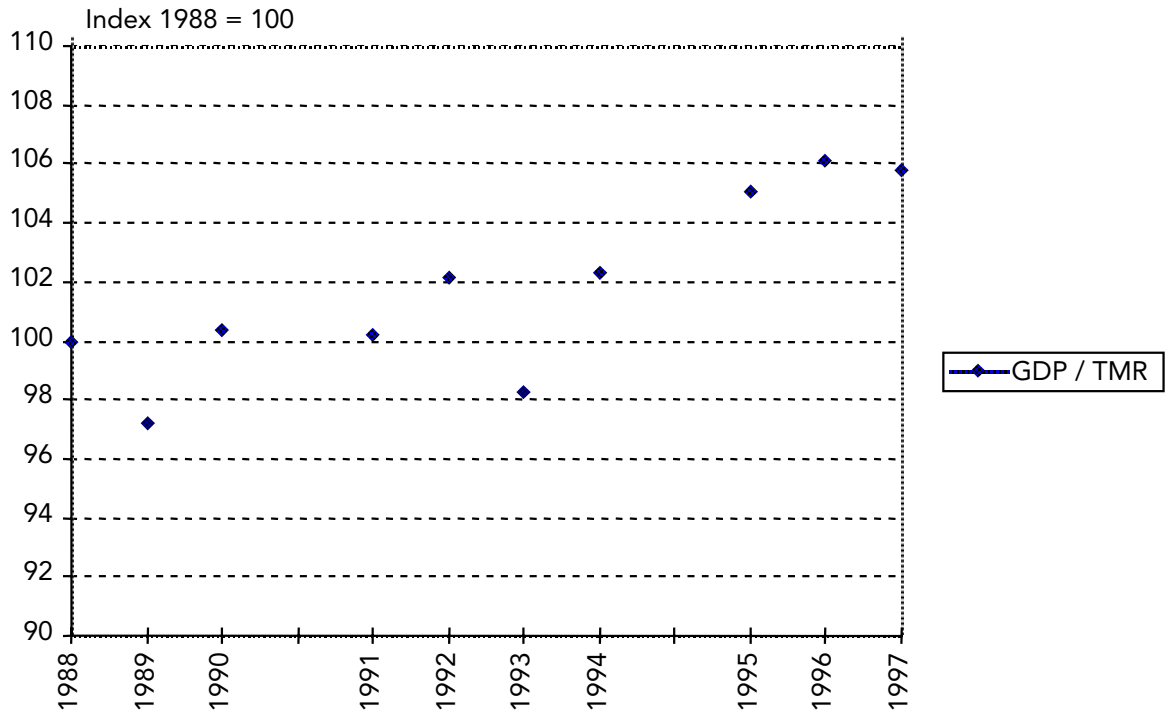
NB: GDP in thousand ECU at constant prices of 1985. DMI of Member States includes intra-EU trade, but the DMI of the EU does not.
Source: Wuppertal Institute.

Heading towards increased material productivity and dematerialisation, countries of Group C are challenged to stabilise material requirements while growing further in economic terms. Countries of Group B have already proved that further economic activities do not necessarily need more material resources, and should strive forward to absolute delinking. Countries of Group A are ahead and should continue and strengthen activities which lead towards dematerialisation and resource efficiency.

The trend of material productivity of GDP, expressed by the ratio of GDP to total material requirement, for the EU was investigated from 1988 to 1997 with respect to EU-12, excluding the former GDR, EU-12 including the former GDR and EU-15 (Figure 14). No significant decoupling of total material requirement from GDP could be observed within the individual short time series studied. Available data indicate a constant trend of total material productivity within the three periods. The slight stepwise increase from 1994 to 1995 was due to the integration of three new Member States with relative high resource productivity. Within the EU as a whole economic growth has generally been associated with increased TMR.

The overall performance of EU-15 will depend on the success of each of the Member States to define and implement policies which foster a further development of increased resource productivity. A variety of measures can be taken to support technological and societal innovation. Improved information and education, the implementation of demand-side management and recycling strategies, the shift towards service provision instead of selling hardware and an integrated resource management on various levels may all contribute towards this future.

Figure 14: Material productivity as GDP/TMR in EU, 1988 to 1997



GDP = gross domestic product (given at constant prices for 1985); TMR = total material requirement (tonnes)
NB: 1988 to 1990 refers to EU-12 excluding the former GDR; 1991 to 1994 refers to EU-12 including the former GDR; 1995 to 1997 refers to EU-15.

😐	No significant decoupling of total material requirement from GDP could be observed within the individual short timescale studied. A slight increase from 1994 to 1995 was due to the integration of three new Member States with relative high resource productivity. Within the EU as a whole economic growth has generally been associated with increased TMR.

9. Conclusions

The expansion of the EU has been associated with significant impacts on resource requirements on a per capita basis:

- With the reunification of Germany the domestic resource extraction increased while the resource requirements via imports decreased. As a consequence, TMR per capita remained nearly constant. Subsequent to the integration of the former GDR, domestic resource extraction and associated environmental burden was significantly reduced.
- With respect to the future integration of candidate Member States one may expect an analogous development afterwards, with a shift from domestic resource extraction to increased import-based resource use. Thus, especially in those countries of eastern Europe which still largely depend on domestic mining, the domestic environment will be released from heavy pressures after integration due to technological conversion and a shift in supply. However, without effective measures to increase the resource efficiency of material supply, the environmental burden through resource requirements will increasingly be shifted to other countries.
- The integration of the technologically well-developed countries like Austria, Finland and Sweden has led to a further decrease in per capita domestic resource extraction. However, this was counterbalanced by increased demand for foreign resources.

Domestic resource extraction within the territory of EU-15 amounted to 30 t/cap. in 1997.

- After the integration of the former GDR, domestic TMR comprised 33 t/cap. The subsequent reduction was primarily due to a decline in lignite production.
- The use of energy carriers changed from coal to gas and oil and thus towards raw materials with a higher resource efficiency.
- Whereas energy carriers had ranked first in domestic TMR in 1985, construction minerals have been the domestic priority resource since 1994.

Foreign resources of EU-15 amounted to 20 t/cap. or 40 % of TMR in 1997.

- Thus the imports and their hidden flows may not be neglected when monitoring the sustainability of the resource supply of the EU's economy.
- Import-based resources are primarily determined by rather volatile metal imports, secondly by imports of energy carriers.
- Imports of precious metals significantly influence the foreign resource base of the EU. Here more information is required on the specific hidden flows of precious metals.
- The same applies for precious stones other than diamonds. So far no valid data is available on the specific hidden flows of precious stones which may be expected to add noticeably to TMR.

The major constituents of TMR of EU-15 are fossil fuels, minerals, and metals. Thus, any political measure which significantly reduces the requirements for those

resources may effectively contribute to an increased overall materials productivity. This study corroborates those efforts which emphasise the necessity to:

- implement the targets of the Kyoto Protocol, reduce the consumption of fossil fuels and increase the efficiency of energy use in industry, transport and households;
- increase resource productivity of the construction sector, foster dematerialised methods of construction, limit the expansion of transport infrastructure and the sprawl of urban systems;
- implement a recycling economy in order to reduce the requirements for primary resources, foster the markets for secondary resources, and support recycling on different levels.

The direct material input (DMI) comprises the amount of primary materials used for further processing, thus also indicating the volume of wastes and emissions later released at other places and in other forms.

- There are indications that DMI may be regarded as a proxy measure for TMR. If this could be corroborated by further studies, the effort for international comparisons could be significantly reduced.
- DMI in the territory of EU-15 declined only slightly from 1988 to 1997. In most of the Member States economic growth has been linked to increased DMI, irrespective of the level of GDP.
- Some countries with higher GDP managed to increase further economic growth with equal or even slightly reduced DMI, thus proving that absolute delinking is possible.

The study proved that total material requirement (TMR) can be determined for an economic region such as the EU.

- The main obstacles to the establishment of a longer timescale have been associated with varying numbers of Member States leading to — normal — problems regarding inconsistent base statistics. This problem may be overcome by the provision of per capita indicators based on the actual memberships.
- Accounting of TMR results not only in the provision of a highly aggregated indicator for international comparison. It also provides valuable information on domestic resource extraction, resource requirements via imports and the relation between domestic and foreign resource requirements.
  The accuracy of TMR accounting could be improved by:
  - — extended information on specific hidden flows (e.g. precious metals and precious stones; extended statistics on the erosion associated with agricultural harvest);
  - — compilation of a harmonised database of hidden flow coefficients of exported commodities for those countries which have already performed a national TMR study
  - — establishment of a global material resource database with direct material inputs and reference values of hidden flow coefficients for the extraction or harvest of raw materials by countries/regions
  - — use and further development of global model systems integrating material flows into national economic accounts and interlinked trade models (e.g. the Compass model system of Meyer and Uno, 1999, see also Moll et al. 1998).

With respect to the further use of TMR-related information for European statistics, we recommend the following:

- test the applicability and usefulness of EU statistics based on the method described in the technical report (EEA technical report No 56);
- encourage the statistical offices of the Member States, and thereby use their high competence with respect to national data, to develop time series accounts of total domestic material requirements in a commonly agreed data framework;
- establish a European database with international reference data on the resource coefficients for globally traded commodities;
- conduct further studies on TMR and DMI of selected countries in order to evaluate possible correlations;
- monitor the shift in resource requirements and associated environmental pressure to foreign countries and regions outside the EU at adequate intervals;
- support the statistical offices of interested Member States, to monitor progress towards resource productivity.

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