2. 0. Material flows

The challenge for sustainable economic development is to increase the economic welfare and well-being of society while, at the same time, reducing resource requirements to a level consistent with the natural carrying capacity of ecosystems. Production and consumption by human societies have always been linked with the use of natural resources, which, in turn, can often have negative environmental effects.

All countries in the pan-European region face this challenge of sustainable management of resources, and there has been only limited progress in reaching a significantly higher efficiency of resource use and achieving a shift towards the wider use of renewable energy and material resources. Several major trends with respect to current resource consumption by European countries show that:

- *A stabilisation of the level of resource use has been achieved in several western, and central and eastern European countries.*
- *Despite this relative decoupling of resource use from economic growth, in absolute terms, material use still remains at unsustainably high levels with regard to both its volume and its structure.*
- *Central and eastern European countries will face difficulties in curbing growth in the use of resources whilst striving to reach western European levels of economic welfare.*
- *Western European economies increasingly import their raw materials, thereby shifting the associated environmental burden to other regions. A similar trend can be observed in most central and eastern European countries. The countries of eastern Europe, the Caucasus and central Asia are one of the main exporters of raw materials to the European Union.*

2.0.1. Introduction

2.0.1.1. Towards a sustainable use of material-based resources

Most changes in the natural environment are brought about by human activities and by the resulting flows of material. The cycle of this 'industrial metabolism' starts with the extraction of raw materials, then includes material and energy use for production and consumption, continues with recycling, and ends up with final disposal. Continuously high levels of material use have environmental implications as all this material must be extracted, transported, transformed and eventually disposed of, leading to environmental impacts at each stage.

Material flows form the 'bridge' between human activities and environmental impacts (Bringezu, 2002). These can vary greatly from local physico-chemical changes (e.g. acidification) through the effects of excessive nutrients (e.g. eutrophication) and mechanical destruction (e.g. excavation), to more structural effects (e.g. landscape change or habitat disruption). Many of the environmental problems presented in this report are directly or indirectly linked to the material throughput of the economy, for example air emissions as discussed in Chapter 3 and Chapter 5 as well as water abstraction presented in Chapter 8.

There is continuing discussion and debate on how to manage this industrial metabolism in a sustainable way, and even about what is a sustainable level of resource use. So far, robust scientific criteria to determine sustainable levels have only been developed for a limited number of material flows associated with well-known environmental problems (e.g. in the area of climate change, air pollution and hazardous substances). Due to the complexity and limited knowledge of the environmental impacts associated with this industrial metabolism, it does not seem feasible to scientifically determine sustainable levels for all human-induced material flows. However, some general principles — based on the concept of sustainable development and the precautionary principle — have been presented (see e.g. OECD, 2001). They include the following:

- the use of renewable resources should not exceed their long-term rates of natural regeneration;
- non-renewable resources should be used efficiently and their use limited to levels which can be offset by substitution by renewable resources;
- releases of hazardous or polluting substances to the environment should not exceed its assimilative capacity;
- irreversible adverse effects of human activities on ecosystems and on biogeochemical and hydrological cycles should be avoided.

Box 2.0.1. Monitoring the metabolism of the economy: what goes in must come out!

The economy takes in raw materials — from the domestic environment and imports from foreign countries — for further processing, manufacturing, production and consumption. Some materials, such as construction minerals, are stored in buildings and infrastructures for many years. At the end of their useful life, products become waste and may be recycled or finally disposed of in landfills or incineration plants. Hence, the size of the resource input also determines the amounts of subsequent waste and emissions.

Since any resource input will sooner or later become an output, it is possible to account for resource flows in terms of a summary balance. Figure 2.0.1 summarises the main flows involved, and introduces some of the terms used in the balance sheet.

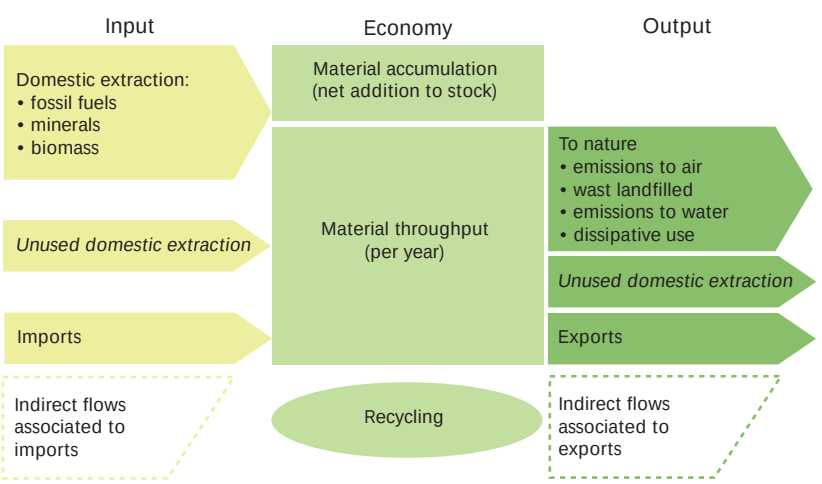
The Statistical Office of the European Communities has developed economy-wide material flow accounts (Eurostat, 2001a), a methodology to provide aggregate descriptions of the total material throughput of economies (excluding water and air). The summary indicators derived from these accounts provide a physical description of a national economy, complementing the greater detail offered by other common indicators (e.g. energy use, waste generation, air emissions). In economic terms, the summary indicators show the dependency on physical resources and the efficiency with which they are used by national economies (Eurostat, 2002). In environmental terms, material input indicators can be used as a proxy for the environmental pressures associated with resource extraction, subsequent material transformation and final disposal of material residuals back to the environment.

Total material requirement (TMR) aggregates all material inputs required by a national economy on a whole life-cycle basis. TMR includes both the direct use of resources (e.g. tonnes of coal used), and the indirect flows associated with domestic extraction (tonnes of topsoil removed to produce construction minerals) and those indirect flows related to the production of imported goods ('hidden flows', for example tonnes of topsoil removed in a foreign country to extract the imported minerals). In economic terms, TMR is a measure of the physical basis of the economy or the total primary resource requirements of all production activities of a national economy. In environmental terms, it is a proxy for potential environmental pressures associated with resource extraction. Since all these material inputs will sooner or later be transformed to material outputs (i.e. emissions, waste), TMR is also a proxy for potential future environmental pressures to the domestic as well as foreign environment on a whole life-cycle basis.

Direct material input (DMI) measures the input of materials that are directly used in the economy, that is, used domestic extraction and physical imports. Unlike TMR, it does not include hidden flows. DMI has been used as a substitute for TMR because data on TMR are more difficult and time-consuming to compile, and hence less readily available than DMI data. Although the DMI indicator may, theoretically, send a wrong signal if a country is decreasing its domestic resource extraction while increasing imports of raw materials, empirical analyses show that there is a correlation between DMI and TMR (see EEA, 2000).

Direct material consumption (DMC) accounts for all materials used by a country and is defined as all materials directly entering the national economy (used domestic extraction plus imports), minus the materials that are exported. In economic terms, DMC reflects consumption by the residents of a national economy. It is also the MFA indicator most closely related to GDP (Eurostat, 2001a). In environmental terms, DMC is a proxy for the potential environmental pressures associated with the disposal of residual materials to the domestic environment.

Figure 2.0.1. **Economy-wide material balance scheme without water and air**



Notes: TMR = domestic extraction (fossil fuels, minerals, biomass) + unused domestic extraction + imports + indirect flows associated with imports; DMI = domestic extraction (fossil fuels, minerals, biomass) + imports; DMC = DMI minus exports.
Source: Eurostat, 2001a

2.0.1.2. Analysing the flows of materials

Material flow accounting (MFA) has been developed as a tool for systematically describing and monitoring industrial metabolism. The underlying principle of MFA is to account for all materials entering and leaving the economic system, based on a mass-balancing approach. MFA can be used to derive indicators on the metabolic performance of national economies, for instance resource inputs, and the efficiency of resource use (Eurostat, 2001a) (see Box 2.0.1).

The basic premise of MFA-based analysis is that the amount of resource flow into the economy determines the amount of all outputs to the environment including wastes and emissions (see Box 2.0.2.). Thus, a reduction in resource inputs will automatically also reduce the outputs — including emissions and waste — thereby lowering pressure on the environment.

So far, economy-wide MFA statistics have been established in only a few European countries. The data presented in this chapter are of a preliminary nature, and are based on several studies. Practically no MFA data are available for eastern Europe, the Caucasus and central Asia (EECCA).

2.0.2. Trends in material flows

2.0.2.1. Progress in decoupling

Recent analysis carried out for the EU Member States and accession countries has shown signs of decoupling materials use from economic growth (Figure 2.0.2.). The productivity of materials and energy has been increasing, and economic added value has been generated with less use of natural resources. This is a positive signal. At the same time, however, material use, in absolute terms, has been high and constant — or even on the increase — in many European countries.

Although direct materials productivity (the ratio between the GDP (gross domestic product) and DMI of a country) in the EU and accession countries has been on the increase over the past decade, DMI has remained fairly constant. This indicates that the environmental burden associated with the use of resources is also likely to have remained constant. Especially worrying signs are the intensive use and high rate of depletion of non-renewable resources, which is not in line with the principle of sustainability. The use of non-renewables is

The productivity of materials and energy has been increasing in many European countries. However, material use, in absolute terms, has been high and constant — or even on the increase.

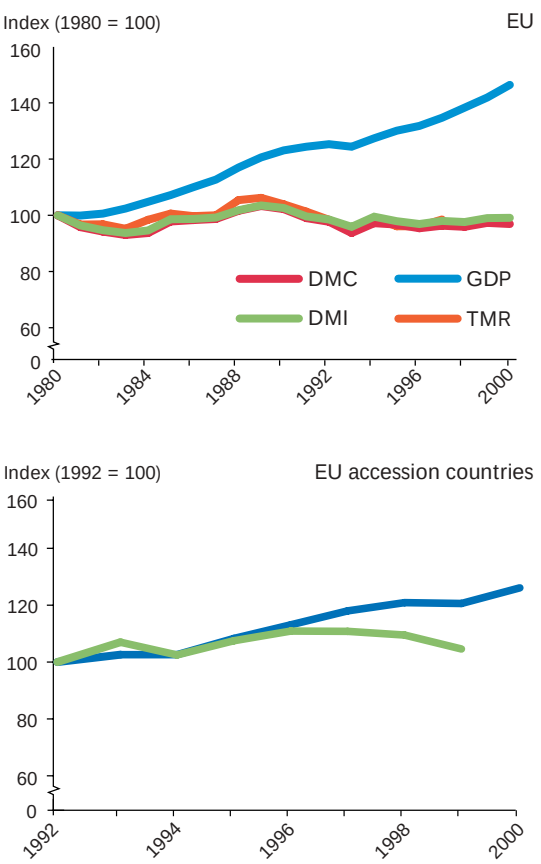
Box 2.0.2. What problems arise from the physical growth of the economy?

In the EU, physical stocks are increasing by about 10 tonnes/capita every year. This results mainly from the construction of new buildings and infrastructure, but also includes accumulation of consumer durables such as furniture, vehicles and household appliances (Bringezu and Schütz, 2001). Such a rapid physical expansion is a reason for concern, and has two major implications.

First, the generation of waste can be expected to rise significantly. This applies in particular to the construction sector. For instance in Germany, the annual amount of construction and demolition waste is expected to double over the next 15–20 years due to the age and composition of the current building stock and infrastructure (Öko-Institut, 1998).

Second the net growth of built-up areas is taking place at the expense of natural productive land (Bringezu, 2002). Such a trend cannot continue indefinitely without jeopardizing renewable materials and energy supply as well as natural habitats and biodiversity.

Decoupling of resource use from GDP by country groupings – EU (a) and accession countries (b) Figure 2.0.2.



Note: See Box 2.0.1 for definitions

Sources: DMI, DMC for EU: Eurostat, 2002; TMR EU: Eurostat, 2001b; DMI accession countries: Wuppertal Institute, 2002; GDP: World Bank and Eurostat, 2003

associated with irreversible changes of landscape and climate, while their continuously high rates of extraction bring about a growing cumulative change in the environment.

2.0.2.2. National variations in resource productivity

When comparing the level of economic prosperity with material use across countries, it is evident that certain countries have been able to achieve high economic welfare with relatively low material inputs. In general, mining and heavy industry require large amounts of material throughput. For example, Italy and the United Kingdom have very different consumption and production patterns from Norway and Finland, which require very high amounts of material input to achieve their high levels of economic welfare. The underlying reason is that the production patterns of Norway and Finland are largely based on the use of natural resources (oil and timber).

In contrast, economies such as Italy and the United Kingdom seem to base their economic welfare to a larger extent on services combined with a lower consumption of fossil fuels and minerals. As a general rule, service-intensive economies tend to be less resource-demanding. On the other hand, some countries with a strong manufacturing sector — such as Germany — have managed to increase their resource efficiency. Two other countries with a high resource productivity are Austria and France, both having a strong agricultural sector and high GDP.

Policy-makers in central and eastern European (CEE) countries and EECCA may want to ask themselves a question while examining Figure 2.0.3: what path will their countries follow as they increase their GDP? Will they be able reach higher GDP per capita while maintaining or even decreasing resource use? Or will their growth be accompanied by significant increase in DMI, for instance through increased reliance on exports of natural resources and minerals?

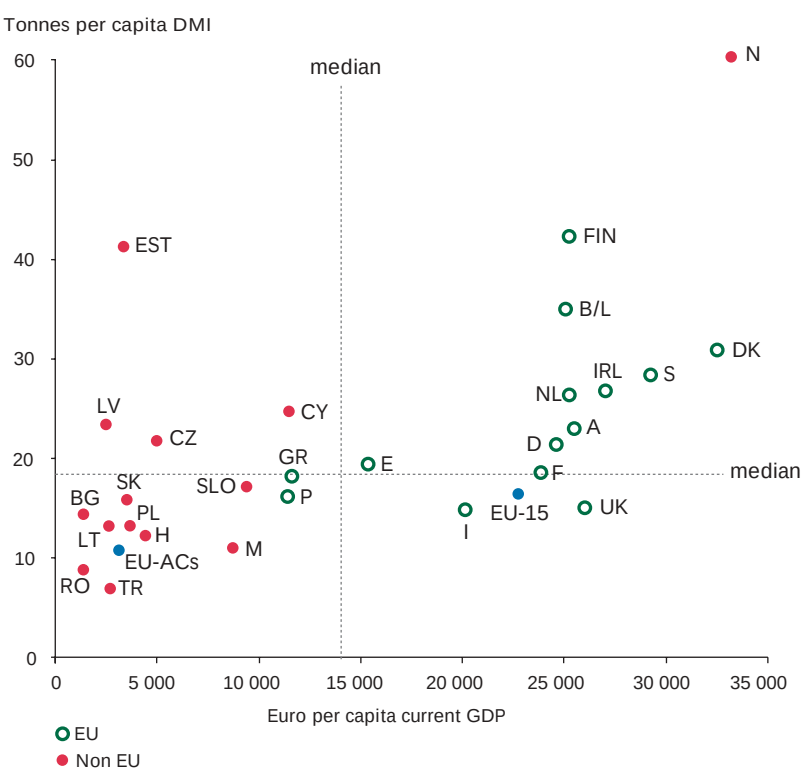
For the accession countries, achieving the EU's level of economic prosperity will require a significant increase in resource productivity. As shown in Table 2.0.1, the direct materials productivity of the accession countries currently stands at 230 euro/tonne, or only 20 % of that of the EU.

In EECCA, extraction of natural resources and exports of raw materials (in particular fossil fuels, metals and biomass) are still the main pillars of economic development. However, the resource productivity (or added value) of this form of resource use tends to be rather low. For the domestic economy, exporting raw materials generates far less economic added value than does processing raw materials into more valuable final goods.

2.0.2.3. Scale and composition of materials use

Continuously high levels and the composition of resource use reflect unsustainable consumption and production patterns. The material flows into the EU

Figure 2.0.3. **Direct material input per capita versus GDP per capita by countries, 1999/2000**



Note: Using DMC (not available for accession countries, however) instead of DMI as the indicator would yield a somewhat different picture, since countries with a high share of exports tend to appear less favourably on the current graph.

Sources: GDP in current prices: Eurostat, 2003; DMI: Eurostat, 2002 and Wuppertal Institute, 2002 (accession countries, Norway)

😐 Central and eastern European countries will find it difficult to avoid moving towards unsustainably high levels of direct material input.

economy — measured as DMI — have remained nearly constant since 1980, fluctuating around approximately 16.5 tonnes/capita per year. The DMC (i.e. DMI minus exports) of the EU has been slightly lower, at some 15.7 tonnes/capita, although for some countries with large amounts of exports, e.g. the Netherlands, Belgium and Norway, the difference has been much higher. The TMR of the EU, which also accounts for the hidden flows, has been fluctuating around 51.8 tonnes/capita.

The DMI of the accession countries — with data available only since 1992 — has been increasing slightly throughout the 1990s, finally reaching some 11.5 tonnes/capita per year. This is about one third smaller than that of the EU, and the difference can be attributed to the significantly lower use of minerals (2.8 tonnes/capita in the accession countries compared with 8.2 tonnes/capita in the EU). The economies of the EU countries seem to require much more mineral resources such as industrial minerals, building minerals and metals which are associated with a large amount of hidden flows (Figure 2.0.4.).

Comprehensive material input indicators are not available for EECCA. Given the limited availability of data, meaningful comparisons can only be made for fossil fuels. Although fossil fuel extraction in EECCA fell during the first half of the 1990s, the extraction rate has now reached 5 tonnes/capita per year. This is high compared with the rest of Europe (about 1.9 tonnes/capita in the EU and the Balkan countries and 2.4 tonnes/capita in the accession countries). As well as the disruption and physical changes to the landscape that result from mining operations, environmental problems associated with such extraordinarily high extraction rates include risks of accidental leakages of gas, spills of oil from pipelines and other related environmental contamination. On the other hand, some argue that despite the environmental consequences, exports of fossil fuels and natural gas are contributing to economic stability in EECCA.

In the EU, the share of non-renewable resources (minerals and fossil fuels) in DMI and DMC has been practically constant over the period 1980–2000, at about 75 %. In the accession countries, the share of non-renewable resources in DMI is lower, at about 60 % and slowly decreasing. Apparently, EU economies require

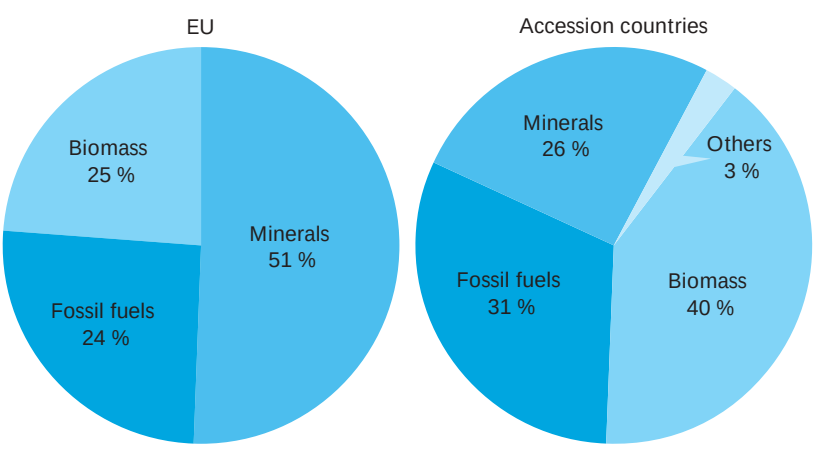
Direct materials productivity of European countries, 1999 (EUR/tonne) — Table 2.0.1.

Austria	1 103	Norway	489
Belgium/Luxembourg	692	Bulgaria	78
Denmark	956	Cyprus	419
Finland	535	Czech Republic	185
France	1 203	Estonia	57
Germany	1 129	Hungary	329
Greece	582	Latvia	73
Ireland	729	Lithuania	109
Italy	1 078	Malta	697
Netherlands	892	Poland	238
Portugal	582	Romania	129
Spain	709	Slovak Republic	204
Sweden	936	Slovenia	500
United Kingdom	1 085	Turkey	328
EU	1 156	Accession countries	230

Notes: Direct materials productivity = GDP in constant prices. DMC, which is in general more suited to being related to GDP, is not available for the accession countries. DMI (unlike GDP) includes imports, hence artificially lowering the resource productivities of the smaller economies which are more open to foreign trade.

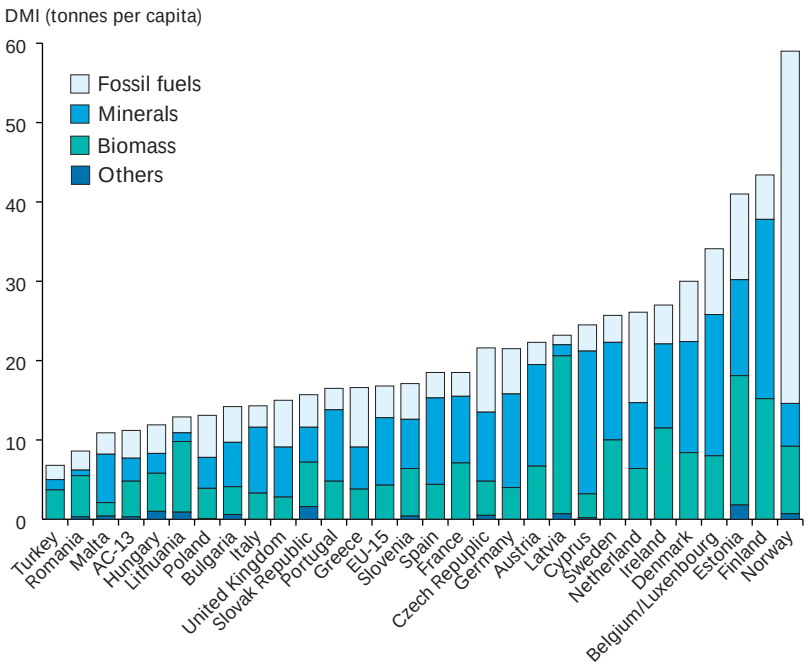
Sources: DMI: Eurostat, 2002 and Wuppertal Institute, 2002 (13 accession countries plus Norway); GDP: Eurostat

Composition of direct material input for EU and accession countries, 1999 — Figure 2.0.4.



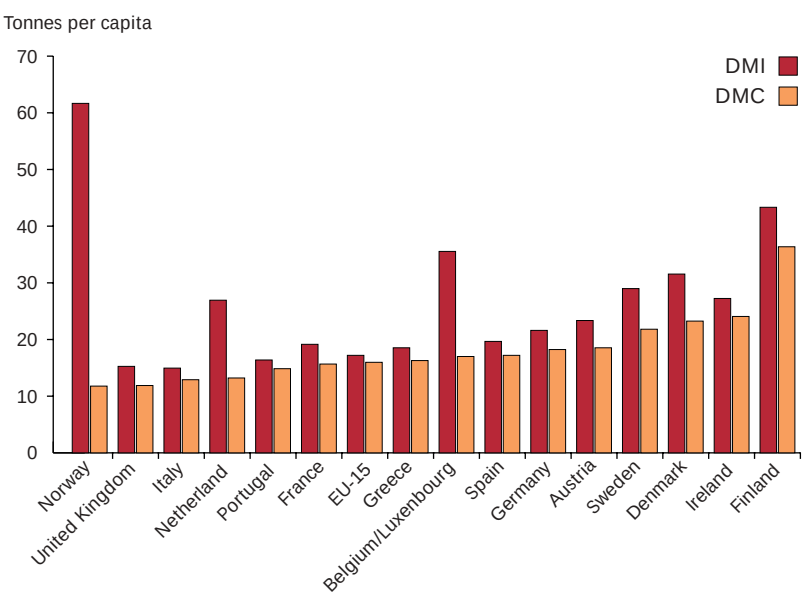
Sources: Eurostat, 2002 and Wuppertal Institute, 2002 (accession countries)

Figure 2.0.5. **Composition of direct material input by countries, 1999**



Sources: Eurostat, 2002 (EU), Wuppertal, 2002 (accession countries, Norway)

Figure 2.0.6. **Comparison of direct material input and direct material consumption — EU, 1999**



Source: Eurostat, 2002

significantly more mineral resources such as metals, industrial minerals and building minerals. Metal resources in particular are associated with a high amount of hidden flows. Fossil fuels — the main cause of climate change problems — are a major component of DMI in both accession countries and the EU, respectively accounting for 31 % and 24 % of the total.

The size and composition of material inputs vary between countries, and depend on the economic base and the size of the country, its consumption and production patterns, and its population density (Figure 2.0.5.). Smaller economies tend to have a higher DMI or DMC. For instance, in Finland and Ireland, this is due to relatively large domestic extractions of biomass. In the case of Estonia, it is high because of the use of oil shale as the primary energy source, and in Denmark, Cyprus and Finland because of the domestic extraction of large amounts of minerals.

The significant difference between DMI and DMC in the Netherlands and Belgium/Luxembourg is due to the 'Rotterdam-effect' (Antwerp and Rotterdam harbours, with their large shipping/export volumes). In Norway, the difference is due to the high exports of fossil fuels, mainly to western European countries (Figure 2.0.6.).

2.0.2.4. Imports on the increase

As a result of increasing external trade and growing imports of natural resources, the resource base of most western European and CEE economies is increasingly shifting abroad. Decreasing domestic extraction and increasing imports of raw materials may be beneficial to the state of the environment of the importing country, and will probably decrease its DMI. At the same time, however, environmental pressures associated with the extraction of resources are moved to other regions of the world.

For the EU, the amount of imported goods has been increasing steadily since the mid-1980s, reaching about 3.8 tonnes/capita in 2000. If one takes into account the indirect hidden flows associated with those imports (e.g. total materials such as metal ores, energy carriers or chemical compounds required to produce an imported good), the increase is even more significant: from around 15 tonnes/capita in the mid-1980s to some 20 tonnes/capita in 1997 (Figure 2.0.7.). On the other hand, both domestic extraction and the associated unused hidden

Increasing imports of resources are resulting in shifting the environmental burden from the consuming to the exporting countries. Imports currently constitute almost 40 % of the total material requirement of the EU, and they grew particularly rapidly during the 1990s.

flows have been decreasing slightly. It is worth noting that imports currently constitute almost 40 % of the TMR of the EU (around 50 tonnes/capita), and these imports grew particularly rapidly during the 1990s.

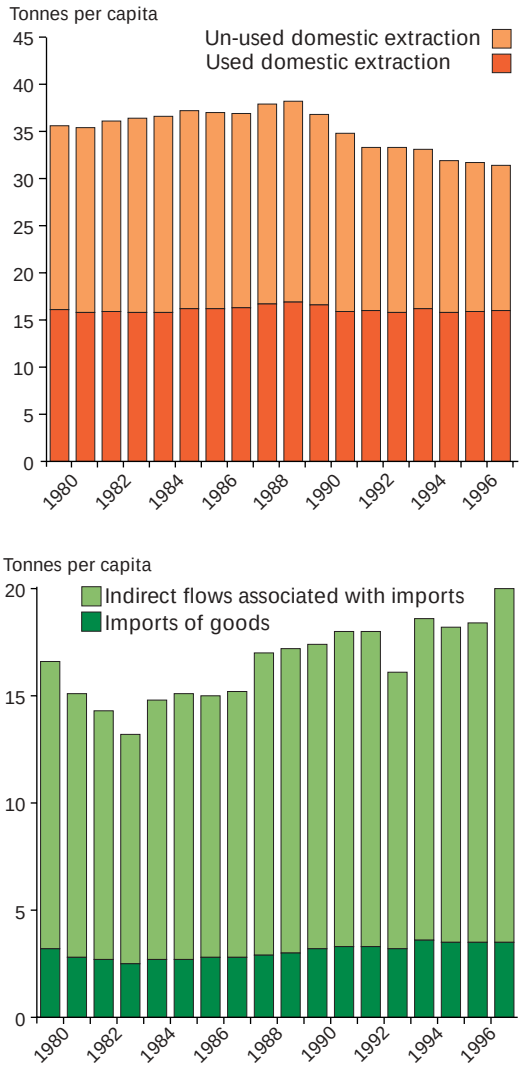
In the accession countries, the amount of imported goods is much lower than in the EU, but the trend has been similar. Imports of goods increased by almost 30 %, from 1.5 tonnes/capita in 1992 to 1.9 in 1999. This situation was probably caused by the closure of uncompetitive domestic extraction industries, combined with increasing integration of the accession countries into the global economy. The trend for increasing imports is likely to continue into the near future.

The increase in imports into the EU is primarily related to fossil fuels and minerals. The increasing import of minerals is an issue of concern because the 'ecological rucksacks' (life-cycle-based resource requirements per tonne of imported final goods) of certain industrial minerals and metals can be extremely high. For example, the ecological rucksack of imported copper is about 150 tonnes per tonne of imported product, that for tin is 6 450 tonnes/tonne, while for precious metals it can even reach 59 000 tonnes/tonne (Bringezu, 2002).

Increasing imports of fossil fuels result in a growing dependency on foreign suppliers. As consumption of fossil fuels contributes to global warming, and at the same time these non-renewable resources will become increasingly scarce in the future, the countries which depend heavily on imports contribute to environmental problems and open themselves to potential economic risks and energy supply security problems.

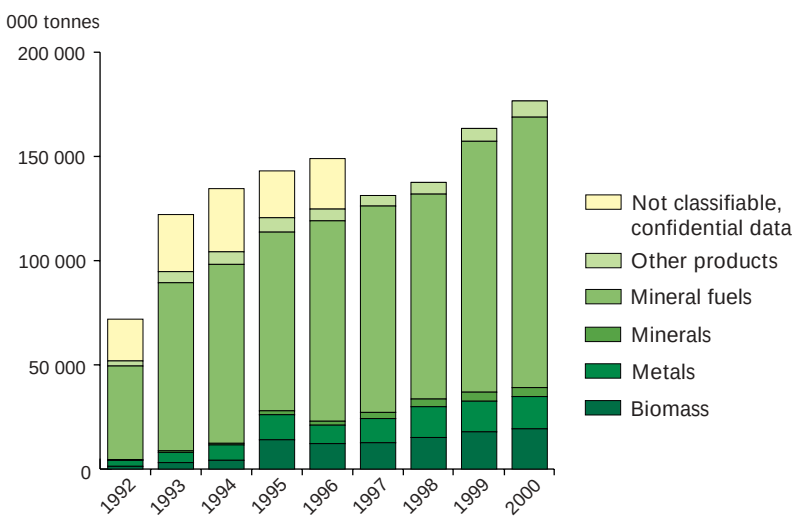
In contrast, the countries of EECCA are typically exporters of mineral resources and fossil fuels. Those with the highest extraction of fossil fuels are the Russian Federation (1 100 million tonnes/year), Ukraine (105

Increasing foreign and decreasing domestic proportion of total material requirement over time, EU Figure 2.0.7.



Sources: Eurostat and Wuppertal Institute

EU imports from eastern Europe, the Caucasus and central Asia, 1992–2000 Figure 2.0.8.



Source: Eurostat COMEXT

million tonnes), Kazakhstan (98 million tonnes) and Uzbekistan (64 million tonnes). On average, about one third of fossil fuels extracted in EECCA are exported, although Kazakhstan, for example, exports almost half of its domestic extraction.

The EU is increasingly importing from EECCA. Currently, about 12 % of the EU's 'physical' imports (i.e. imports measured in tonnes and not in currency) originate from EECCA, particularly as regards fossil fuels and metals (Figure 2.0.8.). This share doubled during the 1990s. Such imports can to some extent be correlated with the environmental problems associated with the extraction of natural resources in EECCA. On the other hand, however, the EU has reduced its domestic extraction and thereby pressures on the domestic environment. It can also be argued that there is a net environmental advantage in shifting to imported resources if the environmental efficiency of extraction is higher in the exporting country than it would be in the importing country.

2.0.3. Policy developments

The issue of consumption and production patterns was addressed for the first time as a policy matter during the United Nations Summit on Environment and Development in Rio in 1992. It was recognised that current patterns, particularly those in the developed economies, were unsustainable and had to be changed. One promising approach was to increase the resource efficiency of economic activities and processes, i.e. to produce greater welfare with less associated use of resources (see Box 2.0.3.).

The importance of the issue was confirmed 10 years later, in August 2002, during the World Summit on Sustainable Development in Johannesburg. It was decided to establish a 10-year framework programme to 'accelerate the shift towards sustainable consumption and production to promote social and economic development within the carrying capacity of ecosystems. This is approached by addressing, where appropriate, de-linking economic growth and environmental degradation, through improving efficiency and sustainability in the use of resources and production processes, and reducing resource degradation, pollution and waste' (UN, 2002). This emphasis may give new impetus to work on consumption and production patterns, as practical achievements in this area in the 1990s have been on a limited scale.

In the EU, the issue of resource use has also been put on the political agenda. The EU's strategy for sustainable development (European Commission, 2001b) emphasised the strategic objective of breaking the link between economic growth, the use of resources and the generation of waste.

Furthermore, the recently adopted sixth environment action programme (6EAP) (European Commission, 2001a; 2002) identified 'sustainable use of natural resources and management of waste' as one of the priority areas. The specific objectives for this area are:

- to ensure that the consumption of renewable and non-renewable resources does not exceed the carrying capacity of the environment;
- to achieve a decoupling of resource use from economic growth, through significantly improved resource efficiency, dematerialisation of the economy and waste prevention.

As part of the work plan, the European Commission is developing a thematic strategy on the sustainable use of natural resources. Through analysis, data collection and evaluation, the goal is to identify priority areas for policy intervention, and to propose the best mix of policy instruments to address the issues identified.

Box 2.0.3. Can absolute reduction of resource use be achieved?

To date, material use per capita has always increased as a result of economic growth. However, there are a few examples of absolute dematerialization, in terms of a decrease in the TMR of the economy.

In the first example, the TMR of the United States declined as a result of a successful programme to reduce erosion in agriculture. In the United States, erosion is a significant factor in agricultural production, and one that contributes strongly to TMR (25 % in 1975, and 15 % in 1994). In 1985, the US government introduced a special programme to pay farmers not to use arable land highly susceptible to erosion. As a result, TMR declined from 99 tonnes equivalent/capita in 1975 to 85 tonnes equivalent/capita in 1994 (Adriaanse *et al.*, 1997).

The second example is more representative of the situation of transition countries. After the reunification of Germany in 1990, the TMR of the country declined significantly, from 88 tonnes equivalent/capita in 1991 to 77 tonnes equivalent/capita in 1997. This resulted from the widespread closures in the former East German lignite mining industries, which were no longer competitive when state subsidies were withdrawn.

In both cases, an absolute decline of TMR resulted from deliberate policy measures, either targeted at a specific resource use, or as a result of changes in the policy framework and economic incentives.

Meanwhile, in the countries of CEE and EECCA, questions of sustainable use of resources and changing consumption and production patterns are only beginning to gain prominence on the environmental policy agenda. Frequently, many of these countries seem more concerned with the problems arising from the restructuring of their economies. However, it is worth underlining that economic restructuring also offers a unique opportunity to establish more sustainable consumption and production patterns.

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