European Environment Agency

Kiev report:

Final Draft Chapter: 2.0 Material Flows

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2.0 Material Flows

2.0.1. Key Trends

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

Several major trends can be observed with respect to current resource consumption:

☺ *In relative terms, the use of resource has been slowly de-coupling from economic growth in many Western and Central European countries.*

☹ *However, in absolute terms, material use still remains at unsustainable levels with regard to both its volume and the structure.*

😐 *Central and Eastern European countries will face difficulty in curbing the growth in the use of resources while 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. Similar trend applies to most CEE countries. The Newly Independent States are one of the main exporters of raw materials to the European Union.*

All countries in the pan-European region face a challenge to progress towards a sustainable management of resources, including reaching a significantly higher efficiency of resource use, and achieving a shift towards the wider use of renewable energy and material resources.

2.0.2. Towards a Sustainable "Industrial Metabolism"

Most changes in the natural environment are brought about by human activities, and the resulting flows of material. The cycle of "industrial metabolism" starts with the extraction of raw materials, then includes material and energy use for production and consumption, continues with recycling, to end up with final disposal. Material flows form the "bridge" between human activities on the one hand, and environmental impacts on the other. (Bringezu 2002).

Those environmental impacts can vary greatly, ranging from local physico-chemical changes (eg. acidification), to effects of excessive nutrients (eg. eutrophication) and mechanical destruction (eg. excavation) to more structural effects (e.g. landscape changes or habitat disruption). Many of the environmental problems presented in this Report are directly or indirectly linked to the material throughput of the economy, such as air emissions as discussed in the Climate Change chapter, or water abstraction presented in the Water chapter.

There is ongoing discussion and debate on how to manage this "industrial metabolism" in a sustainable way. Material Flow Accounting (MFA) has been developed as tool to

describe and monitor 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.

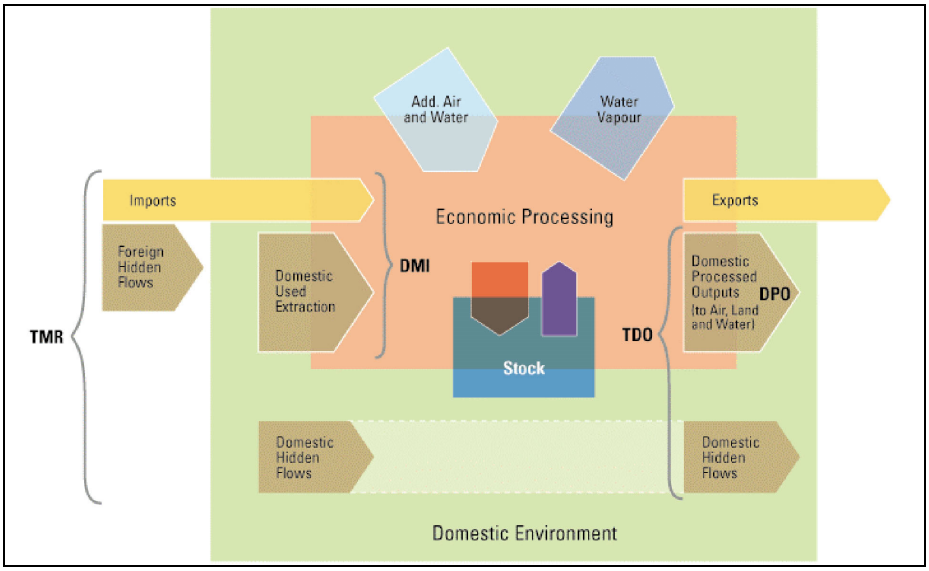
Basic message from MFA is that the amount of resource flow inputs into the economy determines the amount of all outputs to the environment. MFA can be used to derive indicators on the metabolic performance of economies, for instance resource inputs, and the efficiency of resource use (Eurostat 2001) (see Box “: Monitoring the metabolism of the economy: what goes in must come out!”).

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 via imports from foreign countries. A significant part of material extraction has no further use, and is shifted aside, for instance as overburden and mining waste. These so-called hidden flows impact on the local environment, pollute groundwater and contribute to landscape change. The other part of resource extraction is used as direct material input 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 become an output sooner or later, 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.

Figure 2.0.1. Economy-wide material flows and derived indicators (Matthews et al. 2000)



TO THE EDITOR OF THE TEXT: numbers below are values for EU-15, to be incorporated into the figure (tonnes per capita annually): TMR: 50; DMI: 17 imports: 3.5 ; foreign hidden flows: 17; domestic used extraction: 13.5; domestic hidden flows: 15 NAS (net additions to stock): 10; Exports: 1 ; DPO: 12; TDO: 27

Total Material Requirement (TMR) measures the total material basis of the economy, or the total primary resource requirements of all the production and consumption activities. It includes not only the direct use of resources for producing exports, but also indirect flows associated with domestic extraction, and those indirect flows related to the production of goods imported into an economy from other countries.

Direct Material Input (DMI) measures the input of materials used in the economy, that is, all materials which are of economic value, and which are used in domestic production activities. This includes materials contained in imported goods, and resources used in the production of exports.

In general, TMR is a more appropriate indicator for cross country comparisons, because it takes into account all primary resource requirements of a country (including hidden flows of imported commodities), regardless whether they occur in the domestic or a foreign environment. The DMI indicator, which does not include hidden flows of imports, may send a wrong signal if a country is decreasing its domestic resource extraction while increasing imports of raw materials. However, data on TMR is more difficult to compile, and hence less readily available than DMI data.

Both the material throughput and the physical development of the economy are important determinants of the nature and severity of human impacts on the environment. Therefore, sustainable development policies will need to focus on controlling the wider burden of the material throughput, to bring it to the level and composition which can be sustained without jeopardizing the quality of life for the current and future generations.

Source: UK Department for Environment, Food & Rural Affairs 2002

2.0.3. Policy Context

The issue of consumption and production patterns was for the first time addressed as a policy matter during the United Nations Summit on Environment and Development in Rio 1992. It was then recognised that the current consumption and production 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 more welfare with less associated use of resources.

The importance of the issue was confirmed ten years later, in August 2002, during the World Summit on Sustainable Development in Johannesburg. It was decided to establish a ten-year Framework Programme to "accelerate the shift towards sustainable consumption and production to promote social and economic development within the carrying capacity of ecosystems by addressing and, 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).

In the European Union, the issue of resource use has also been put on the political agenda. The EU's Strategy for Sustainable Development (CEC 2001b) emphasised the strategic objective to break the link between economic growth, the use of resources, and the generation of waste.

Furthermore, the recently adopted 6th Environment Action Programme of the European Union (CEC 2001b) identified *Sustainable Use of Natural Resources and Management of Waste* as one of the priority areas. The specific objectives for this area are : (CEC 2001a, p. 50, 53):

> (1) to ensure that the consumption of renewable and non-renewable resources does not exceed the carrying capacity of the environment; and
>
> (2) to achieve a de-coupling 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 Community will soon develop a '*Thematic Strategy on the Sustainable Use of Natural Resources*.' Through the necessary analysis, data collection and evaluation, to goal is to identify priority areas for policy intervention as well as propose best mix of policy instruments to address the identified issues.

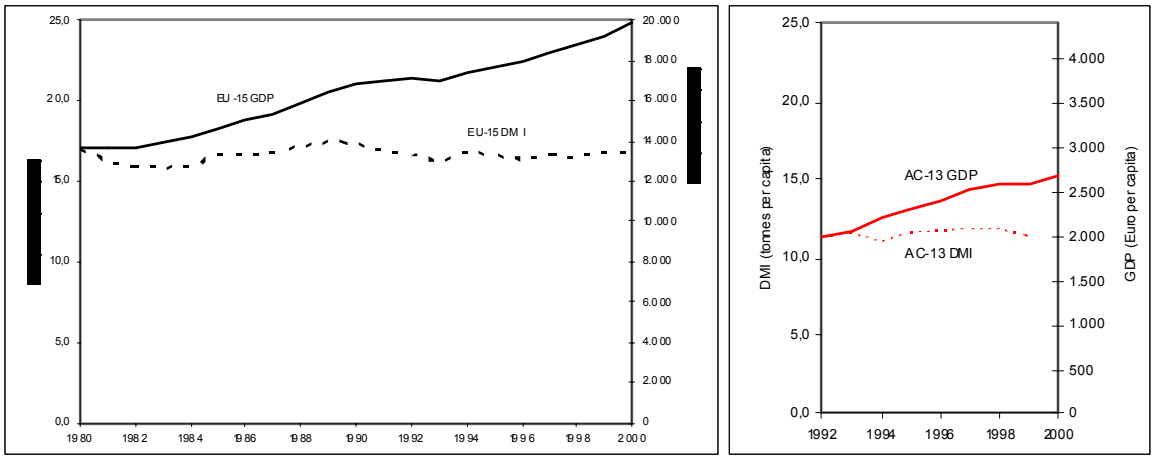
Meanwhile, in the countries of Central and Eastern Europe and the Newly Independent States, the issues of sustainable use of resources and changing consumption and production patterns have not yet been put on the environmental policy agenda. Instead, many of those countries seem more concerned with the problems arising from the restructuring of their economies. However, it is worth to underline that economic restructuring also offers a unique opportunity to establish more sustainable consumption and production patterns.

2.0.4. Findings

Good news and bad news: ☺ relative decoupling achieved but with a ☹ simultaneous increase in absolute material use

Recent analysis carried out for the EU Member States and the Accession Countries (AC) has shown signs of decoupling of economic growth from material use (Figure 2.0.1.). In other words, the productivity of materials and energy has been increasing, and economic value added 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 constantly high or even on the increase in many European countries.

Figure 2.0.1. DMI and GDP per capita over time by country groupings (EU-15, AC-13)



Notes: DMI: Direct Material Input, aggregate of the mass of domestically extracted raw materials (without water and air) which are further processed in domestic industry plus mass weight of imported goods.
Sources: DMI: Eurostat, IFF (EU-15) and Wuppertal Institute (AC-13 + Norway); GDP: World Bank and Eurostat

The material input flows into the EU-15 economy – measured as Direct Material Input (DMI) - have been nearly constant since 1980, fluctuating at approximately 16.5 tonnes per capita annually.

The DMI of the AC-13 – with data available since 1992 – has been slightly increasing throughout the nineties, to finally reach the level of some 11.5 tonnes per capita. This value is approximately one third less than that of the EU-15, and the difference can be attributed to the significantly lower use of minerals (i.e., 2.8 tonnes per capita in the AC-13 compared to 8.2 tonnes per capita in the EU-15). The economies of EU countries seem to require much more mineral resources such as industrial minerals, building minerals and metals, (see Box) with the latter associated with a high amount of hidden flows.

While comprehensive material input indicators are not available for the Newly Independent States, some comparisons can be made for fossil fuels. Although fossil fuel extraction in the NIS countries has been declining in the first half of the nineties, the current extraction rate already amounts to 5 tonnes per capita, which is high compared to the rest of Europe. The corresponding value for the EU-15 and for the Balkan countries is approximately 1.9 tonnes/capita, while for the AC-13 it stands at 2.4 tonnes/capita. Aside from the destruction and physical changes to the landscape as a result of mining operations, other environmental problems associated with such extraordinarily high extraction rates include risks of accidental leakages of gas and spill of oil from pipelines, and other related environmental contamination.

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

In the European Union, the physical stocks increase by about 10 tonnes per capita every year. This

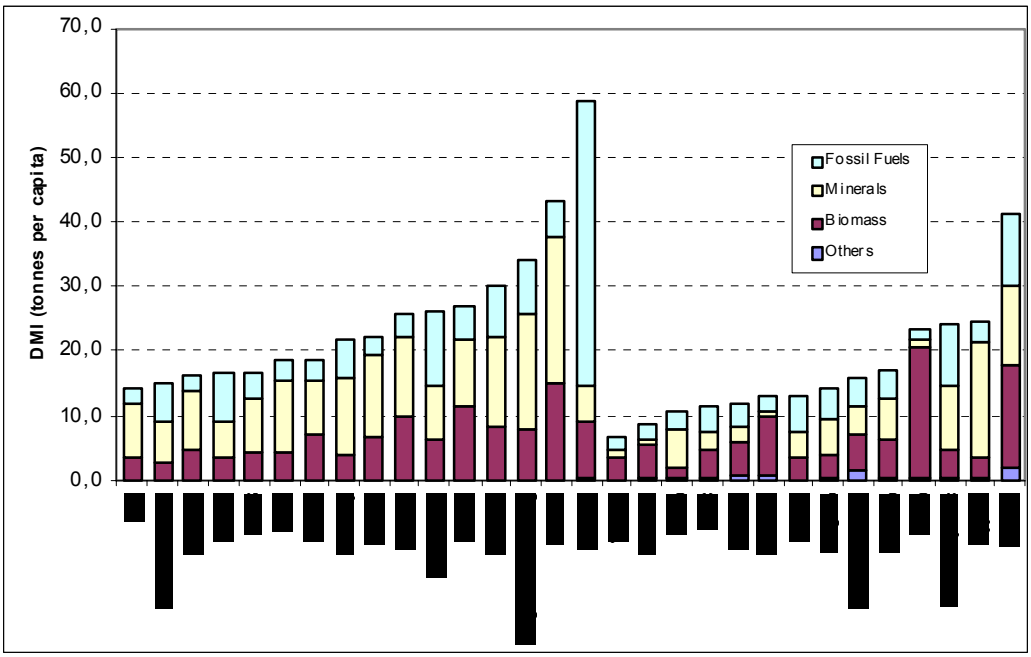
primarily results from construction of new buildings and infrastructure, but also includes consumer durables such as furniture, vehicles, household appliances, etc. (Bringezu and Schütz 2001). Such a rapid physical expansion is a reason for concern, and has two major implications. First, the generation of waste can be expected to rise significantly in the future. This applies in particular to the construction sector. For instance in Germany, the annual amount of construction and demolition waste is expected to double in the coming 15-20 years, due to age and composition of the current building stock and infrastructure (Öko-Institut 1998).
The second major concern is that the net growth of built-up areas takes place at the expense of natural productive land (Bringezu 2002). For instance, over the last 30 years in Germany there has been a linear relation between the increase of built-up areas, and net additions to pysical stock. Such a trend cannot continue indefinitely without jeopardizing renewable materials and energy supply, as well as natural habitats and biodiversity.

☹Continuously high levels and the composition of material use reflect unsustainable consumption and production patterns.

Although direct resource productivity (the ratio between the GDP and DMI of a country) at EU-15 and AC-13 has been on the increase over the last decade, DMI remained fairly constant over the same period. This indicates that the absolute environmental burden associated with the use of resources also remained constantly high. Especially worrying is the intensive use and high rate of depletion of non-renewable resources, which is not in line with the principle of sustainability (Figure 2.0.2). The use of non-renewables is associated with irreversible changes of landscape and climate, while the continuously high rate of extraction indicates a growing cumulative change of the environment.

In EU-15, the share of non-renewable resources in the DMI has been practically constant over the period 1980-2000, standing at a high level of around 75%. In the AC-13, the share of non-renewable resources in DMI is somewhat lower, standing at about 63% and following a slightly decreasing trend. Non-renewable fossil fuels - the main cause of the climate change problems - are a major component of DMI in both AC-13 and EU-15, respectively accounting for about 33% and 25% of the total.

Figure 2.0.2. Main components of DMI by countries and country groupings, 1999



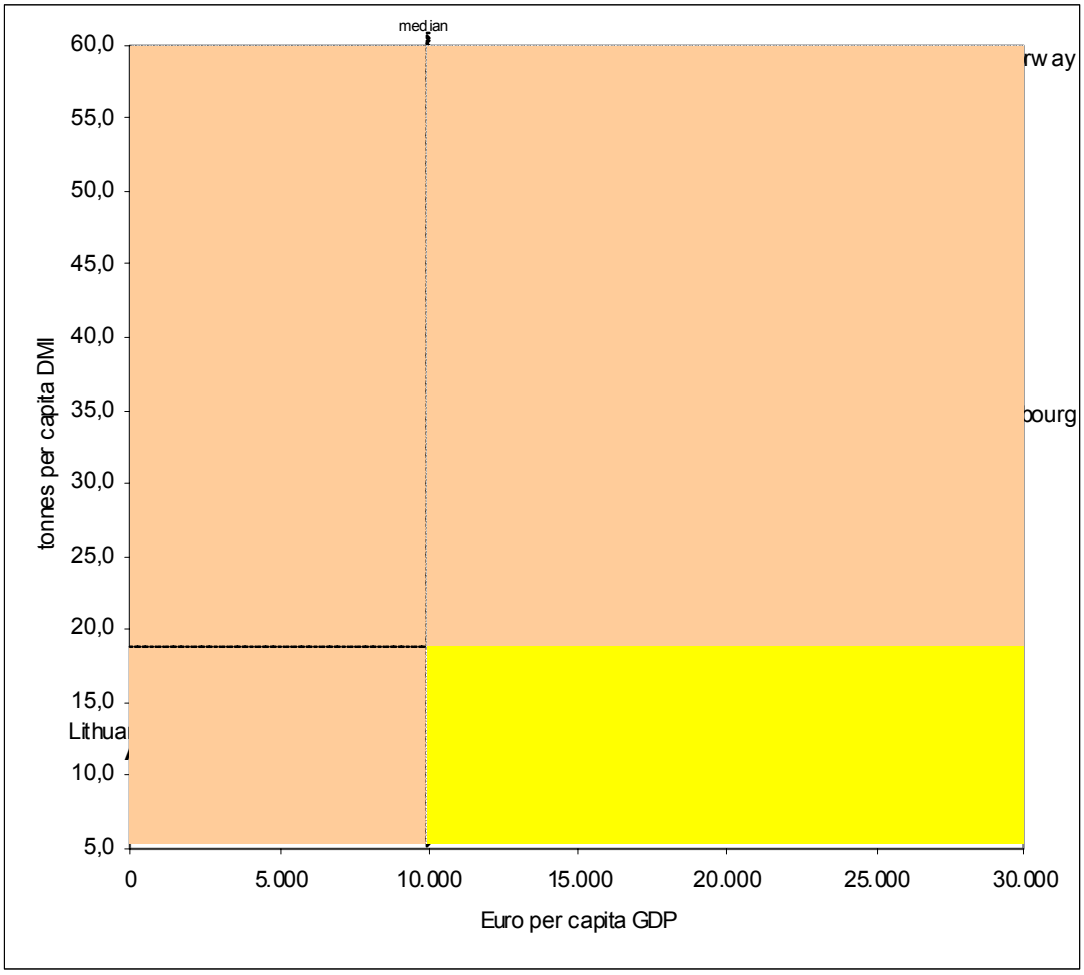
Notes: Fossil fuels: hard coal, lignite, oil, gas; Minerals: metals, industrial minerals, construction minerals; biomass: from agriculture, forestry, fishing and hunting
Sources: DMI: Eurostat, IFF (EU-15) and Wuppertal Institute (AC-13 + Norway)

The size and composition of materials inputs vary across the countries (Figure 2.0.2.), and depends on the economic structure of a country, and on its consumption and production patterns. For instance, some countries – Estonia, Ireland, Latvia, Lithuania, Romania and Sweden – have a relatively high share of renewable resources in their DMI. This reflects the fact that those countries have been able to organise their consumption and production patterns with less dependency on non-renewable resources.

When comparing the level of economic prosperity with the material use across countries, it is evident that certain countries have been able to achieve high economic welfare combined with relatively low material inputs (Figure 2.0.3.). 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 than Norway and Finland, which both require very high amounts of material inputs to achieve their high levels of economic welfare. The underlying reason is that the economies of Norway and Finland are still largely based on the use of natural resources (oil, timber), with Norway as a net oil exporter also contributing to global warming. Although Finland has reduced its domestic extraction of ores, its metal manufacturing actually increased due to growing imports.

In contrast, economies such as Italy and the UK seem to base their economic welfare to a larger degree 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, even 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 a high GDP levels.

Figure 3: DMI per capita versus GDP per capita by countries, 1999/2000



Sources: GDP: Eurostat; DMI: Eurostat, IFF (EU-15) and Wuppertal Institute (AC-13 + Norway)
note to layout editor: the horizontal bar is the median as well.

Policy makers in the CEE and NIS countries may want to ask themselves another question while examining Figure 2.0.3.: how will the position of their countries on the Figure change as they increase their GDP ? Will they be able to follow the model of UK and Italy, or will their growth be based accompanied by significantly increased DMI ?

☹ NIS and CEE countries will face difficulty in trying to avoid moving towards unsustainably high levels of DMI

For the Accession Countries, achieving EU's level of economic prosperity will require a significant increase in their resource productivity. As shown in Table 2.0.1, the direct resource productivity of the AC-13 stands currently at 226 Euro/tonne, or only 20% of that for the EU-15. To achieve the current EU-15 average, the direct resource productivity of the AC-13 economies would have to increase by a factor of 5.

Table 2.0.1: Direct resource productivity[1] of European countries, 1999 (Euro per tonne)

Austria	1099	Norway	485
Belgium/Luxembourg	692	Bulgaria	76
Denmark	957	Cyprus	418
Finland	535	Czech Republic	163
France	1200	Estonia	57
Germany	1126	Hungary	329
Greece	578	Latvia	72

[1] Direct Resource Productivity (GDP / DMI)

Ireland	724	Lithuania	109
Italy	1079	Malta	697
Netherlands	889	Poland	238
Portugal	583	Romania	128
Spain	709	Slovak Republic	199
Sweden	896	Slovenia	500
United Kingdom	1083	Turkey	328
EU-15	1152	ACC	226

Sources: DMI: Eurostat, IFF (EU-15) and Wuppertal Institute (AC-13 + Norway); GDP: World Bank and Eurostat

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

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

To date, material use per capita has always been increasing as a result of economic growth. However, there exist a few examples of absolute dematerialization, in terms of a decrease in Total Material Requirement of the economy. In the first example, TMR of the United States declined as a result of a successful policy programme to reduce erosion in agriculture. In the US, erosion is a significant factor in agricultural production, and one that contributes strongly to TMR (25% in 1975, and 15% in 1994). In 1985, 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 t/capital in 1975 to 85 t/capita in 1994 (Adriaanse et al. 1997). The second example is more representative for the situation of transition countries. After the reunification of Germany in 1990, TMR of the country declined significantly from 88 t/capita in 1991 to 77 t/capita in 1997. This resulted primarily from the widespread closures in the 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. In the latter case, mines operated within a centrally-planned economy proved to have high resource consumption. The example showed how market-driven reduction of subsidies for resource intensive industries can significantly contribute to an overall increase in resource productivity.

For AC-13 countries, it is likely that further convergence of their technological base and production and consumption patterns with those of EU-15 will lead to an increase in materials and resource use, if no action is taken to increase the resource efficiency (see Figure 3).

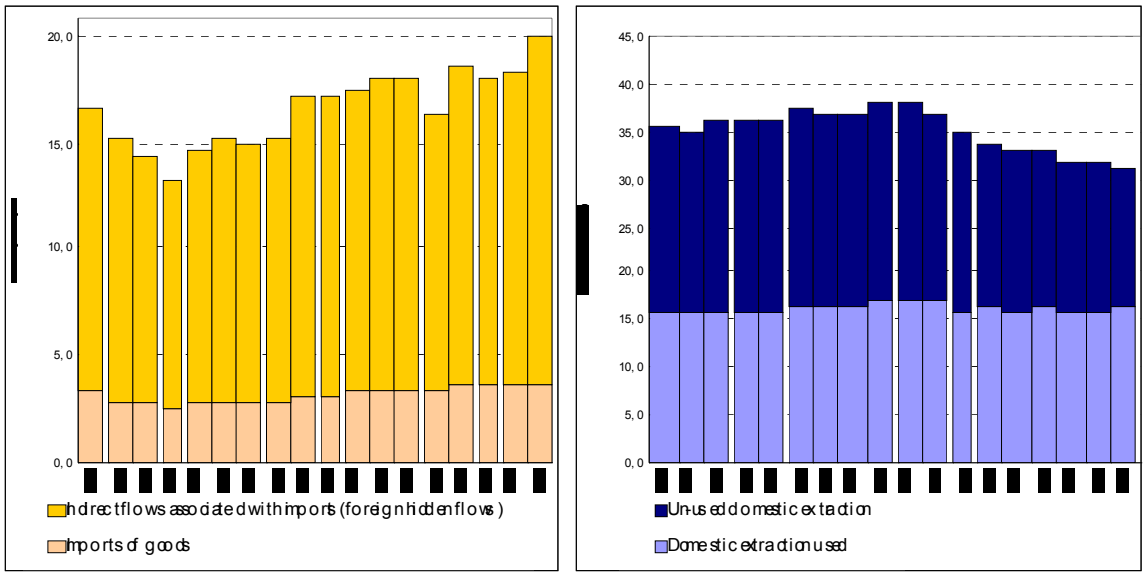
For instance, if Poland were to reach the current GDP level of the EU-15 (19,883 Euro/capita) without improving its current resource productivity (i.e. 238 Euro per tonne), this would lead to an increase in DMI to approximately 83 t/capita. On the other hand, increasing its direct resource productivity by a factor of 5 in order to reach the productivity level of the EU-15 would result in DMI of 16.7 tonnes per capita, which is still higher than the current level of material use in Poland (13.1 tonnes per capita). Finally, reaching the EU-15's GDP level while maintaining the amount of material use constant would put the Polish economy ahead of the EU-15 member states, but would also require an increase of direct resource productivity by a factor of 6.

☹ Problem shifting through importing resources – a reason for concern

As a result of external trade and increasing imports of resources, the resource basis of most Western and Central European economies is being increasingly shifted abroad. The decreasing domestic extraction and increasing imports of raw materials may be beneficial to the state of the environment of the importing country (and will likely decrease its DMI), but at the same time, 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 steadily increasing since the mid-eighties, to reach the level of about 3.8 tonnes per capita in the year 2000. If one takes into account the indirect "hidden" flows associated with those imports (eg. total materials such as metal ores, energy carriers, or chemical compounds required to produce an imported vehicle), the increase is even more significant: from around 15 t/capita in the mid-eighties to some 20 tonnes per capita in 1997 (Figure 2.0.4.). On the other hand, domestic extraction and the associated unused hidden flows have been decreasing slightly. It is worth noting that, with TMR at 50 tonnes per capita, imports currently constitute almost 40% of the Total Material Requirement of the EU, and the imports grew particularly fast during the nineties.

Figure 2.0.4. Increasing foreign and decreasing domestic part of TMR over time, EU-15



Sources: TMR: Eurostat and Wuppertal Institute

In the AC-13, the amount of imported goods is much lower than that of the EU, but the trend has been similar. Imports of goods increased from 1.5 tonnes per capita in 1992, to 1.9 tonnes per capita in 1999. This situation is likely caused by the closure of uncompetitive domestic extraction industries, combined with the increasing integration of those countries into the global economy. The trend for increasing imports is likely to continue in the near future.

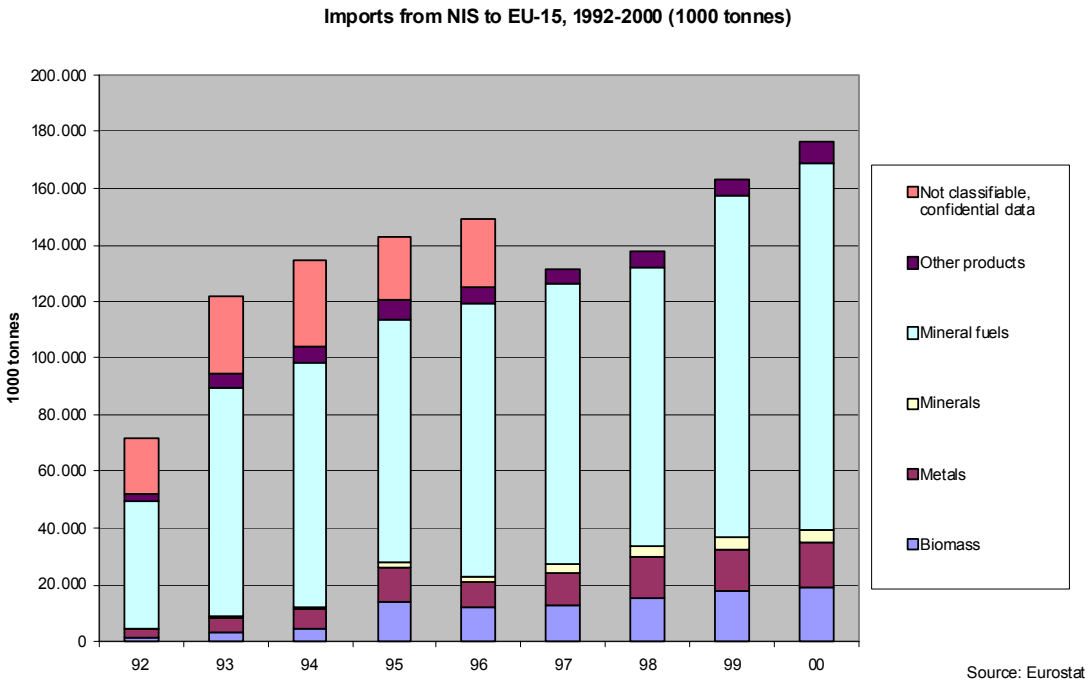
The increase in imports to the EU is primarily related to fossil fuels and minerals. The increasing import of fossil fuels results in a continuous dependency on foreign suppliers. As consumption of fossil fuels contributes to global warming, and at the same time these non-renewable resources will become increasingly scarce in the future, the EU countries not only contribute to environmental problems, but they potentially also open themselves to economic risks and to global security problems. The increasing import of minerals is an issue of concern because the "ecological rucksacks" (life-cycle based resource requirements per tonne of imported final good) 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 copper, that for tin is 6450 tonnes per ton of tin, while for precious metals it can even reach 59000 tones per ton of imported good (Bringezu 2002).

In contrast, NIS countries are typical exporters of mineral resources and fossil fuels. The countries with the highest extraction of fossil fuels are Russia (1,100 million tonnes), Ukraine (105 million tonnes), Kazakhstan (98 million tonnes), and Uzbekistan (64 million tonnes). On average, about one third of fossil fuels extracted in NIS - or about 1.5

tonnes per capita - is exported, although for instance Kazakhstan exports almost half of its domestic extraction.

The EU is one of the main importers from NIS countries. Currently, about 12% of EU's "physical" imports (that is imports measured in tonnes and not in currency) originate from NIS countries, particularly as regards fossil fuels and metals, and this percentage doubled throughout the nineties. Hence, EU economies are also to a great extent responsible for the environmental problems associated with the extraction of natural resources in NIS countries.

Figure 2.0.5. Imports from NIS to EU-15, 1992-2000 (1000 tonnes)



Sources: Eurostat COMEXT

In concluding, the countries of the pan-European region will face a challenge to achieve a more sustainable management of resources, including the need to significantly increase the efficiency of resource use, to limit the dependence on non-renewable energy and material resources, and to curb the trend for shifting environmental problems via increased imports.

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